Schistosomiasis Control in China: Strategy of Control and Rapid Assessment of Schistosomiasis Risk by Remote Sensing (RS) and Geographic Information System (GIS)

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Abbreviations

CAPM	Chinese Academic Preventive Medicine
CCCP	Central Committee of Chinese Communist Party
CDC	Center of Disease Control
DALY	Disability-adjusted life year
DN	Digital Number
ETM	Enhanced Thematic Mapper
ETM+	Enhanced Thematic Mapper Plus
GBD	Global Burden of Disease
GeoTIFF	Geographic Tagged Image File Format
GIS	Geographic Information System
GPS	Geographic Positioning System
IPD	Institute of Parasitic Diseases
JRMC	Joint Research Management Committee
MOH	Ministry of Health
NDVI	Normalized Difference Vegetation Index
NIH	National Institute of Health
NIR	Near-infrared
OEDC	Office of Endemic Diseases Control
RS	Remote Sensing
SCI	Scistosomiasis Control Initiative
STI	Swiss Tropical Institute
TC	Tasseled Cap
TDR	Tropical Disease Research
TM	Thematic Mapper
WHO	World Health Organization
WB	World Bank
WBLPP	World Bank Loan Project

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Zusammenfassung

Die Bilharziose ist eine der häufigsten parasitären Infektionskrankheiten, vor allem in den Tropen und Subtropen. In 76 Ländern ist die Krankheit momentan endemisch und stellt dort eine grosse Bürde für die betroffenen Bevölkerungsgruppen dar. Es wird geschätzt, dass rund 650 Millionen Menschen in Gebieten leben, wo sie dem Risiko der Bilharziose-Infektion ausgesetzt sind. Rund 200 Millionen Menschen sind mit dem Krankheitserreger infiziert, 120 Millionen Menschen zeigen Symptome der Krankheit und 20 Millionen leiden an schweren Folgen der Krankheit. Obwohl in China Morbiditätskontrolle gemäss Empfehlungen der Weltgesundheitsorganisation während mehr als 20 Jahren implementiert wurde, gehen Experten davon aus, dass weiterhin 90 Millionen Menschen dem Risiko der Krankheit ausgesetzt sind, und dass rund 820'000 Leute mit dem Erreger (*Schistosoma japonicum*) infiziert sind. Die totale Fläche der Habitate von den Zwischenwirtsschnecken (*Onchomelania hupensis*) wird auf 3'436 km^2 geschätzt, vor allem in den fünf Seenregionen entlang dem Yangtzefluss. Anhui, Jiangsu, Jiangxi, Hubei und Hunan sind die am stärksten betroffenen Provinzen. Die Kontrolle der Bilharziose in den Sumpfgebieten der Poyang-Seenregion gestaltet sich als besonders schwierig. Es wird geschätzt, dass rund 79.5% der akuten Bilharziose Fälle und 96.4% der Zwischenwirtshabitate in diesen Gebieten konzentriert sind. Mit dem grossangelegten 10-jährigen Weltbank-Darlehensprojekt (1992-2001), welches zum Ziel hatte, die Bilharziosekontrolle in China voranzutreiben, ist die Prävalenz der Krankheit massive zurückgeganen. Dennonch sind die Reinfektionsraten hoch in den Gebieten wo die Endemizität besonders hoch ist.

Im ersten Teil der hier vorliegenden Dissertation fasse ich die 50-jährige Geschichte der Erfahrung und Expertise China’s in der Kontrolle der Bilharziose zusammen. Ich diskutiere vor allem die Strategie der Morbiditätskontrolle und fasse die Erfolge des Weltbank-Darlehensprojektes zusammen. Dabei komme ich zum Schluss, dass China in der Tat die Morbidität der Krankeit erfolgreich bekämpft hat, und diese Strategie somit der wichtigste Bestandteil bleiben wird, um die Krankheit im Schach zu halten und dabei zum Schutz der Gesundheit der Menschen beitragen wird. Die Kosten sind jedoch beträchtlich. Im zweiten Teil dieser Dissertation beschreiben ich die erfolgreiche Entwickung von einem Computer-Model zur Identifizierung von Habitaten der Zwischenwirtschnecken, und somit den

Haupttransmissionsorten der Krankheit. Die drei wichtigsten Erkenntnisse können wie folgt zusammengefasst werden. Erstens, mit einer einfachen visuellen Klassifizierung typischen Landnutzungsmustern mit Hilfe von Satelitenbildern lassen sich prominente Schneckenhabitate identifizieren. Zweitens, Extraktion von einem Vegetationsindex und dem sogennanten “Tasseled Cap Brightness Index“ lassen sich Prediktionen weiter verbessern. Drittens, die Verwendung von Pufferzonen (600 und 1200 m) um die vorhergesagten Schneckenhabitate ermöglicht eine akurate Einteilung von Gebieten mit hoher (> 15%), mittlerer (3-15%) oder tiefer Bilharzioseprävalenz (< 3%). Preliminäre Validierung des entwickelten Models mit Schneckenfelduntersuchungen in der Poyang-Seenregion ergab, dass das Model präzise Voraussagen zur Scheckenverteilung macht. Anwendung des Models erlaubt somit eine rasche und kostengünstige Identifikation von Risikogebieten der Bilharziose, was von grosser Bedeutung ist für das nationale Bilharziose Kontrollprogramm. Das Model beinhaltet ausserdem grosses Potential für das Monitoring der Krankheit ganz allgemein und das Monitoring des Three Gorges Reservoirgebietes.

Summary

Human schistosomiasis remains one of the most prevalent parasitic infections in the tropics and subtropics. The disease currently is endemic in 76 countries and territories and continues to be a major public health concern, especially in the developing world. It is estimated that 650 million people are at risk of infection. Among the 200 million people actually infected, 120 million are symptomatic and 20 million suffer severe disease. Although morbidity control – in line with recommendations put forth by the World Health Organization – has been carried out in China for more than 20 years, it is estimated that 90 million people still live in areas where they are at risk of infection, and 820,000 people are infected with the parasite, i.e. *Schistosoma japonicum*. The estimated area of intermediate host snail habitats comprise 3,436 km^2, concentrated in the 5 lake regions along the Yangtze River that include the provinces of Anhui, Jiangsu, Jiangxi, Hubei and Hunan. The marshlands of the Poyang Lake region represent some of the strongholds for the transmission of *S. japonicum*. In these settings, for example, the percentages of acute cases and intermediate host snail habitats represent 79.5% and 96.4%, respectively. With the World Bank Loan Project (WBLP) to control schistosomiasis in China, the overall prevalence of *S. japonicum* was significantly reduced, but in highly endemic areas the re-infection rates are high.

In the first part of the present thesis, I summarize the 50-year history of China's experience and expertise in schistosomiasis control. Particular emphasis is placed on morbidity control and achievements made by the WBLP carried out between 1992 and 2001. Reviewing this body of literature reveals that morbidity control of schistosomiasis in China has been successful, and hence this strategy will continue to form the backbone of protecting people's health. However, total expenditures have been considerable, and with the termination of the WBLP there is concern that schistosomiasis might re-emerge. In the second part of this thesis, I describe the successful development of a novel compound model to identify the habitats of *Oncomelania hupensis*, the intermediate host snail of *S. japonicum*, and hence the identification of high-risk areas of disease transmission. There are three findings that warrant particular notion. First, visual land use classification on multi-temporal Landsat images was performed for preliminary prediction of *O. hupensis* habitats. Second, extraction of the normalized difference vegetation index and the tasseled cap transformation greenness index were used for improved snail habitat prediction. Third, buffer zones with distances of 600 and 1,200 m were made around the predicted snail habitats to differentiate between high (>15%), moderate (3-15%) and low risk of *S. japonicum* infection prevalence (< 3%). Preliminary validation of the compound model against ground-based snail surveys in the Poyang Lake region revealed that the model had an excellent predictive ability. The model therefore holds promise for rapid and inexpensive identification of high-risk areas, and can guide subsequent control interventions, such as whether mass or selective chemotherapy should be employed. The model can also be used for diseases surveillance in general and the monitoring of ecological transformations on the transmission dynamics of *S. japonicum*, for example in the Three Gorges Dam area.

1 Schistosomiasis Burden and Control

1.1 Global Status of Schistosomiasis and its Control

Schistosomiasis remains one of the most prevalent parasitic infections in the world. It is endemic in 76 countries and territories, and continues to be a global public health concern in the developing world. It is estimated that 200 million people are infected, of whom 120 million are symptomatic and 20 million have severe disease. Six hundred million people are at risk of infection. Because it is a chronic insidious disease, it is poorly recognized during early stages, and becomes a threat to development as the disease disables men and women during their most productive years. It is particularly linked to agricultural and water development schemes. It is typically a disease of the poor who live in conditions which favor transmission and have no access to proper care or effective prevention measures.

1.2 The Burden of Schistosomiasis in the World

It has to be acknowledged that some progress has been made in schistosomiasis control. A number of countries have come to appreciate the public health importance of schistosomiasis and have initiated control since the 1980s or before. In China and Japan, the high morbidity and mortality due to *S. japonicum*, leading to the disintegration of communities and the consequent reduction in agricultural production justified control (Chen, 1999; Tanaka and Tsuji, 1997). In Brazil, schistosomiasis was one of the leading public health problems (Katz, 1998). Control was initiated in Egypt because irrigation is the mainstay of agriculture and it was felt that morbidity due to schistosomiasis would hamper production (Mobarak, 1982). Also in Morocco, the intensive development of irrigated agriculture and the associated threat of an expansion of the schistosomiasis problem were the incentives to initiate national control (Laamrani et al., 2000). Some of these endemic countries, such as Brazil, China, the Philippines and Egypt, have been able to sustain national control programmes for a prolonged period and have succeeded in reducing morbidity to very low levels. Others, such as the smaller Caribbean Islands, the Islamic Republic of Iran, Mauritius, Morocco, Puerto Rico, Tunisia and Venezuela, are nearing elimination or have already achieved this goal (WHO, 2001a).

Recently, the concept of disability-adjusted life year (DALY) was developed in order to assess and refine estimates of the global burden of disease (World Bank 1993). For sub-Saharan Africa, a morbidity burden due to schistosomiasis of 3.5 million DALYs has been estimated. In comparison with all other communicable disease, schistosomiasis therefore ranks in tenth position, after respiratory infections (31.6 million DALYs), malaria (31.5), diarrhea disease (30.4), HIV infections (18.4), measles (16.1), tuberculosis (13.7), sexually transmitted disease excluding HIV (7.5), tetanus (5.8), and pertussis (4.8) (Murray, 1994). According to the WHO report of burden of schistosomiasis in the World (GBD, 1990) show that Africa is 1369 DALYs, Egypt is 129, Brazil is 73 and China is 22 (Figure 1).

Schistosomiasis is the second most prevalent tropical disease in Africa after malaria and is of great public health and socio-economic importance in the developing world. There are five major species of schistosomiasis which infect man. One is found in Africa and in South America, two are confined to Africa, and the other two are found only in the Far East in China and the Philippines.

Schistosoma mansoni – causative agent of intestinal bilharzia – originated in Africa but was carried to South America with the slave trade where, because a suitable snail host existed, it became established, particularly in Brazil and the Caribbean. It is transmitted by snails of the genus Biomphalaria (link), aquatic snails that thrive in irrigation canals and along lake shores.

Schistosoma haematobium – which causes urinary bilharzia – is transmitted by snails of the species Bulinus, which inhabit less permanent water bodies, as during their life cycle they prefer a period of aestivation (hibernation) in mud, during a dry season.

The third major species of schistosome is *S. japonicum*, historically widespread in Japan, China and the Far East, and was the cause of widespread and gross morbidity and mortality. It affects not only man but also domestic and wild animals. However, due to effective control measures carried out in Japan during the 1940's and 1950's, this parasite has been eradicated in Japan. Snail control and socio-economic development in China, has reduced the prevalence in most areas, and this species is now found only in isolated foci in China and some islands in the

Philippines. *S. japonicum* is transmitted by an amphibious snail (species *Oncomelania*) which makes snail control relatively easy (SCI, 2002).

It has been argued that, compared to Brazil, Egypt and Sudan, sub-Saharan Africa had less schistosomiasis related morbidity (Gryseels, 1989). However, numerous reports of substantial late-stage morbidity have been published in the international literature prior to 1970. Also, a recent review study has quantified the clinical morbidity associated with schistosome infections in sub-Saharan Africa and came up with substantial numbers of ill or seriously ill cases (Van der Werf et al., 2002). The same study also suggested that the number of deaths involving schistosomiasis in sub-Saharan Africa may be as high as 200,000 per year.

1.3 The Strategy of Schistosomiasis Control Suggested by WHO

The strategy of control in high burden areas

The main principles of schistosomiasis control, such as the concept of morbidity control and the recommendation that it should be implemented through the primary health care system, have not changed since the second meeting of the WHO Expert Committee in 1991 (WHO, 1993). Nevertheless, some elements in schistosomiasis control have changed during the last decade. Praziquantel--the drug of choice for all forms of schistosomiasis--has become significantly less costly. Several brands of good quality, generic praziquantel are on the market today (Doenhoff et al., 2000; Appleton and Mbaye, 2001). The cost of an average treatment with this drug has come down to less than 0.30 USD--less than a customary user fee in health services. This clearly opens up perspectives for a more generalised access to the drug. It also implies that presumptive treatment, on the basis of early clinical symptoms, or universal treatment on the basis of epidemiological criteria, have become cost-effective in an increasing number of endemic situations (Guyatt et al., 1994; Carabin et al., 2000). As praziquantel is a safe drug, it can be delivered at the most peripheral levels of the drug delivery system, as well as by non-medical personnel.

There is also a growing consensus that morbidity control, infection control, and transmission control are different objectives and should be recognized as distinct and consecutive steps on the road from morbidity control in the strict sense towards elimination. In high burden areas, the first step to take in control is indeed to deal with morbidity in the strictest sense. The WHO has recently reviewed the strategy for the implementation of morbidity control in high burden areas (WHO, 2002), with emphasis on better targeting of control interventions, and a more cost-effective and sustainable implementation of control strategies. The WHO Expert Committees for the Prevention and Control of Schistosomiasis and Soil-transmitted Helminthiases, in their first joint meeting held in Geneva (8-14 October, 2001), have defined a simple, easy and affordable control package adapted to the prevailing public health context in high burden countries. Integration of control in existing structures and decentralisation of decision-making and delivery are key elements for sustainable control in this package. Minimal implementation targets have been laid down in a recent WHO resolution (WHO, 2001 b).

The strategy of control in low burden areas

It has been demonstrated, in a number of formerly heavy burden countries, that sustained schistosomiasis control efforts have resulted in significant reductions in morbidity and mortality. Where disease is no longer a public health issue, sustainable transmission control focusing on hygiene and sanitation improvement, and environmental management, should become the major operational components. These will decrease the risk of resurgence of schistosomiasis as well as strengthen and continue improvements to other public health goals as well. As the endemic level decreases, new objectives need to be defined, in view of possible elimination. This, in turn, leads to new approaches and algorithms defined according to local situations. Cost-effectiveness and decentralized decision making are also crucial issues in low transmission areas. Optimal use of resources is indeed necessary to maintain sufficient control pressure to avoid resurgence.

Schistosomiasis is currently not considered as a disease targeted for elimination. In the absence of a global effort to eradicate or eliminate schistosomiasis, WHO has not established a standardized Certification Process which would involve the setting up of an international commission, and the definition of standardized criteria to certify that schistosomiasis is not endemic any more in a given country or area. Moreover, the fact that schistosomiasis has a complex transmission cycle, that a symptomatic carrier state is common, and that for certain parasite species an animal reservoir exists, would make the definition of criteria for elimination a complex issue. Also, interruption of transmission may be reached in different ways: by the 'sterilization' of the parasite reservoir, by the elimination of the snail intermediate host (e.g. through the use of competitor snails), by an improvement in socio-economic status and hygiene so that contamination and infective water contact does not occur any more, or by a combination of these scenarios. The issue is further complicated by the risk of re-introduction of the disease in an area where it was previously eliminated, particularly where water resource development and/or migration occurs (Engels et al, 2002).

1.4 Schistosomiasis japonicum

A major difference from the other human schistosomes is the wide range of domestic and wild mammals which the parasite can use as a definitive host. These zoonotic infections considerably complicate control activities. *S. japonicum* was formerly widespread in mainland China, on Japan, on a number of islands in the Philippines, and in an isolated focus on Sulawesi.

Strain differences within *S. japonicum* and its intermediate hosts have been reported in China (He et al, 1991; Iwanaga, 1997; Qian et al, 1996). The adults worms live around the gut in the mesenteric branches of the hepatic portal vein. Their reported preference for the superior mesenteric veins may be an artifact due to studies using very high infections in experimental animals: late pathological lesions of the human colon suggest a wider distribution (Chen, 1991). Typical, oval eggs with a lateral spine reduced or absent are voided in the feces, and the molluscan phase of the life cycle takes place in (semi)amphibious prosobranch snails of the genus *Oncomelania*. Human disease, as with all human schistosome, is primarily associated with those eggs that fail to escape from the definitive host and the various mechanisms used in their entrapment, isolation and destruction. These mechanisms involve the formation and resolution of granulomata around such eggs, particularly those swept to the liver and lungs. Neurological complications due to granulomata formation in the brain are believed to be more frequent in *S. japonicum* than in other schistosome infections. There is evidence that early acute disease in *S. japonicum* infections is more severe than for other schistosomes and that it can recur after super infection later in life among people with chronic infections (Chen, 1991).

S. japonicum also affects a wide range of mammalian hosts, which include different species of wild, domestic or feral animals (Gang, 1993). This feature of *S.*

japonicum might make it the most difficult schistosoma species to control. The clinical manifestations of schistosomiasis japonica are similar to those produced by *S. mansoni* infections; more severe manifestations are generally ascribed to *S. japonicum* infections. This is attributed to the latter's higher egg output and pattern of laying eggs in large aggregates resulting in more florid and presumably destructive tissue reaction. For example, compared to *schistosomiasis mansoni,* serum-sickness-like syndrome or Katayama fever, growth retardation in children, acute cerebral manifestations and hepatosplenic disease are more pronounced in *S. japonicum* (Chen, 1989). In addition to the above features, the mechanism of granuloma formation in *S. japonicum* infection seems to be an immediate manifestation rather than a manifestation of delayed hypersensitivity reaction to egg antigen (Warren et al, 1975). Modulation of this granulomatous reaction around eggs deposited in the liver tissue can be transferred by serum but not cells from chronically infected animals (Olds et al,1982). Furthermore, immunity to *S. japonicum* seems to be species-specific (Maloney et al, 1985). Thus, vaccine preparations against *S. mansoni* or haematobium may not be protective against *S. japonicum*.

China represents the largest endemic area of *S. japonicum* infection. In the 1950's, 10 million persons were estimated to be infected (Mao and Shao, 1982). In China, infection is endemic mainly in areas along the Yangtze River and to the south of the river basin. These areas include 348 counties in 10 provinces, the Shanghai Municipality and the Guangxi Autonomous Region (Qian et al, 1985).

In the Philippines, despite control efforts, *S. japonicum* infection remains a serious health problem affecting 167 towns of 24 provinces, with the more prominent foci existing in Sorsogon in the northern part of the country, in Oriental Mindoro, Samar, Leyte, Bohol in the central part, and in Mindanao in the south. In the island of Samar and Leyte alone, there are over 500,000 infected individuals, thus placing approximately 10 million Filipinos at risk (Olveda et al, 1983).

In Indonesia, schistosomiasis is localized in two limited foci in Lake Lindu valley and Napu valley in Central Sulawesi. It was estimated in 1984 that around 7000 persons were at risk of infection and about 4000 persons had an active infection (Hadidjaja et al, 1985). In Japan, there were formerly five endemic areas: four in Honshu and one in Kyushu. As a result of an intensive control program, only a few small snail colonies now exist and no new human infections have been reported since 1978 (Tanaka et al, 1984). It was estimated that in 1986 about 100,000 patients with chronic schistosomiasis remained in Japan (Tanaka et al, 1984).

1.5 The Epidemiological Situation and Control of Schistosomiasis japonicum in China

Archeological studies have revealed that schistosomiasis japonica has a very long history in China. *S. japonicum* eggs were identified in a female corpse dating back to the Western Han dynasty some 2,100 years ago (Mao and Shao, 1982; Qian, 1986) that was exhumed in 1971 in Hunan province. Schistosome eggs were also found in the liver of another corpse buried 100 years earlier in Jianglin Hsien, Hubei province (Zhou, 1994). In old volumes of traditional Chinese medicine (Mao and Shao, 1982), a description of clinical symptoms resembling Katayama fever (acute schistosomiasis) can be traced back to 400 B.C. The first reported clinical diagnosis in modern China was made by an American physician in 1905 in Hunan province (Logan, 1905).

After the founding of the People's Republic of China in 1949, large-scale epidemiological surveys were carried out by Chinese scientists to determine the incidence, prevalence, and intensity of *S. japonicum* infections. The results revealed that schistosomiasis was endemic in 380 counties comprising 12 provinces south of the Yangtze River. Approximately 12 million people were infected, with an additional 100 million people at serious risk. A total of 14,000 square kilometers of infected *Oncomelania* flood plains were identified as potential transmission zones despite remarkable successes in schistosomiasis control achieved over the previous four decades (Chen, 1999; Chen and Feng, 1999; Mao, 1986) (Figure 2).

In China, endemic areas of schistosomiasis were found along the Yangtze River and extended southward covering 10 provinces (Jiangsu, Zhejiang, Anhui, Jiangxi, Hunan, Hubei, Yunnan, Sichuan, Fujian and Guangdong), the municipality of Shanghai and the autonomous region of Guangxi. There were 5102 townships in 373 counties (cities) where the disease was endemic. The northern geographical distribution limit was Baoying County, Jiangsu Province (33°15'), south to Yulin County, Guangxi Zhuang Autonomous Region (22°5'), east to Nanhui County, Shanghai Municipality (121°51') and west to Yunlong County, Yunnan Province (99°50'). The highest altitude of the endemic areas was about 3000 meters above the sea level (in Yunnan Province) and the lowest at sea level (in Shanghai Municipality). The most heavily endemic areas were located along the Yangtze River and the 2 biggest lakes (Poyang and Tongting). 10 million persons were estimated to be infected by that time and the population at risk of the infection was higher than 100 million. The copulative areas of *Oncomelania* snail habitats were estimated to be 14.8 billion m2 (Mao and Shao, 1982; Qian, 1986).

Schistosomiasis is a strictly regional endemic disease. It is dependent on the *Oncomelania* snail distribution. There are 3 types of endemic areas, i.e., marshland and lake regions, hilly and mountainous regions and plain regions with water-way networks. In the plain regions, the snails are distributed along river systems and schistosomiasis spreads widely. In the marshlands of the lake regions influenced by the Yangtze River (1st degree water level), snails spread out in vast areas. The marshlands submerged for about half to 5 months are suitable for snail breeding. The snail distribution in the marshlands influenced by the 2nd degree water level, usually inside embankments, is similar to that in the plain region with water-way networks. The snails in the swamp and lake regions can easily spread by floods and the transmission of schistosomiasis occurs almost year-round. In the hilly and mountainous regions, the snails are distributed along ditches, channels and river systems but are isolated from one another. There are snails in the same river system either in upstream or downstream. These areas are economically underdeveloped and unaccessable. The mode of transmission is through daily activities and production.

Based on statistic data in 1989, among 373 counties formerly endemic for schistosomiasis, 158 have declared transmission interruption, while in 110, it is under effective control. 72% of 373 endemic counties have reached the criteria for transmission interruption and transmission control (Yuan, 1989).

In 1989, 118 counties were still endemic for schistosomiasis. Hubei, Hunan, Jiangxi, Anhui and Jiangsu provinces have problems with schistosomiasis control in the lake regions, whereas schistosomiasis in mountainous regions is mainly in the provinces of Yunnan and Sichuan. According to the nation-wide sampling survey conducted in 1989, it was estimated that there were about 1.63 million infected persons and among them (endemic areas), about 55,000 were advance cases. The number of infected cattle was estimated to be 200,000 and the area of snail habitats was 3.6 billion m2. Population at risk of infection was estimated to be greater than 44 million. The stool egg positive rate in residents of different provinces was 14.4% in Hunan, 13.5% in Hubei, 5.5% in Jiangxi and 8.6% in Anhui. In Jiangsu Province, the infection rate was very low. The number of the infected persons in the 5 provinces was estimated to be 1.35 million, making up 83% of 1.63 million infected ones estimated for the whole country. The mountainous endemic areas are mainly distributed in Yunnan and Sichuan provinces with the stool egg positive rate being 16.8% in Yunnan and 4.4% in Sichuan. The number of infected population was estimated to be 227,000 in the 2 provinces, accounting for 14.4% of the whole infected population in China. During the period of 1981-1989, the number of acute cases had increased year by year. The *Oncomelania* snail habitats in whole China were 3.63 billion m2, of which 3.46 billion m2 (95.5%) were in the 5 provinces of lake regions, 143 million m2 (3.9%) in the 2 provinces of mountainous regions, and 20 million m2 (0.6%) in the plain regions with water-way networks (OEDC, 1993).

The reasons why the endemic areas of lake and mountainous types are the focal and difficult points of schistosomiasis control are related to local ecological and epidemiological features of the disease. Socio-economic factors also play an important part in transmission of schistosomiasis in these areas (Zheng et al, 1997). In lake regions, in the beaches of lakes, the Yangtze River and others lakes connected with the River, the water levels are unstable, dry in winter and floody in summer. In these areas, weeds are growing, and reeds and willow trees are planted, which are favourable for snail breeding. If these plantations are distributed in irrigation canals inside embankment, the ecological environment of snails is similar to that in plain region with water-way networks. Snail control approaches with either mollusciciding or dam circling each have their difficulties. The former will influence the ecological balance and the latter will reduce flood dredging. People in lake regions are densely populated and they and their cattle frequently contact infested waters for various reasons (Yuan, 1989; Yuan, 1992a,b). As a result, they get infected and reinfected very easily, and prevalence rates in the lake areas are usually maintained at considerably high levels. These densely populated lake regions are one of the main bases of marketable grain production areas in China. The mountainous regions refer to high and steep mountains in Yunnan and Sichuan provinces. With moderate climate and plentiful rainfall, snails breed in valley brooks, grassy lands of hill slopes and irrigation ditches, and on the vertical slopes of terraced fields, and so on. Snails are distributed in an independent way, and the transmission areas are scattered as individual land parcels. Sometimes, two places are separated only by a peak; one is endemic, whereas the other is non-endemic. These vast mountainous areas are sparsely populated by poor national minorities. Communications and transportation are difficult, and so is the control work.

After more than 40 years hard work in control, at present the criteria for elimination schistosomiasis have been reached in 236 counties (cities) in 5 provinces, whereas in 52 counties (cities) the criteria of transmission control have been reached (Guo, 1999). Generally, two historical phases can be separated during China's fight against schistosomiasis. In the early phase (pre 1980), comprehensive approaches with emphasis on snail elimination were carried out and later (after 1980) chemotherapy has been the key approach, supplemented with snail elimination in areas with high transmission potential, and health education.

Up until 2002, among 418 counties, the transmission had been interrupted in 247 counties, and in 63 counties, the transmission had been under control, whereas in 108 counties (Figure 3 and Figure 6), the disease was still endemic. The total number of infected persons was 820,000 and 90 million persons were at risk of the infection (Chen et al., 2002), and the areas of snail habitats were 3.436 billion m2 and 96% of them was in the marshland and lake areas (Figure 5).

Although schistosomiasis control gained great success during the past 40 years, schistosomiasis transmission still exists in most of the marshland and mountain areas. During the World Bank Loan Project, effect chemotherapy reduced human infection and intensity. However, it is difficult to interrupt the transmission. 1) The gains from chemotherapy are not easily consolidated due to reinfection in residents with a rate between 5 and 47% after chemotherapy according to different authors (Yuan, 1992a,b). Synchronous chemotherapy both for humans and bovines has been implemented in Hunan since 10 years. However, human infection rates fluctuated around 6% since the second year of chemotherapy, i.e. 1988. It was difficult to further decrease the infection rate due to a high re-infection rate. The high-risk persons are the key target population for chemotherapy and need treatment more than once a year. 2) Bovine is the main infection source of schistosomiasis, in China, 40 mammalian species have been found infected with *S. japonicum*. Cattle, buffaloes and pigs are of great importance in contamination of the marshland (Guo et al, 2003). It is quite difficult to treat those animals of these areas. Mobile cattle population recently increased along with economic development. Cattle are income sources for the farmers in the region. Although cattle were screened yearly and chemotherapy was given during WBLP period in some areas, the number of infected animals did not substantially decrease. Cattle are a more important source of infection than humans in swamps and lakes. If we can't control the cattle from schistosome infection, it will very difficult to control the transmission of schistosomiasis. 3) After the serious flood in the Yangtze River valley in 1998, both snail-infested areas and the possibility of infection with *S. japonicum* through water contact have increased. Furthermore, in order to reduce the impact of floods, the China State Council adopted a policy on anti-flooding by 'returning cultured land into the lake and relocating of farmers from endemic areas to newly established towns'. It is one of the new issues in the schistosomiasis control program that needs investigation, since the policy may contribute to the increase of snail habitats on a large scale, increase of possibility for people in close contact with infested water, and increase the prevalence of schistosomiasis in some areas. 4) The impact of the Three Gorges Dam project on transmission of schistosomiasis in the middle and lower reaches of the Yangtze River is still unclear. There is a need to strengthen the investigation and surveillance on the impact of water levels on the distribution and dispersal of *Oncomelania* snail in the Yangtze River valley.

1.6 Schistosomiasis in Jiangxi Province

Jiangxi province is one of the most serious endemic areas for schistosomiasis japonica in China. In 1924, an epidemiologist by the name of John Faust first found the disease in Shahe Township, Jiujiang County of Jiangxi Province. Jiangxi was thereafter, officially declared an endemic areas with schistosomiasis. It was later discovered that 33 counties/cities and 314 townships (farms) were endemic with schistosomiasis according to a province-wide survey during the period of 1953-1956. In 1957, two more counties and 58 townships were also discovered endemic for schistosomiasis. It can then be concluded that a total of 35 counties (cities) and 372 townships (which includes 2,374 administrative villages) were endemic for schistosomiasis (Hu et al, 1999).

In the 1950s, statistical data revealed that in Jiangxi, the total area of snail habitats was about 2.4 billion m2. The cumulative number of infected subjects was

530,000 and that of buffalo/cattle was about 50,000. Among the infected subjects, advanced and acute cases accounted for 8% and 5% of the total respectively. The population at risk of infection was 15.5 million, 6.97 million and 3.91 million in endemic county-, township-, and administrative village-level respectively (Zhang et al, 2002).

According to geographical patterns of endemic areas and ecological characteristics of the vector snail, schistosomiasis endemic regions in Jiangxi have been stratified into two types, namely, marshland and lake regions and hilly and mountainous regions. In the 1950s, the endemic situation of schistosomiasis was extremely serious in various endemic areas of Jiangxi province. Average infection rate for inhabitants was above 10%. Over 30% prevalence was found among inhabitants living around the Poyang Lake, some even up to 80%. There were 40,000 – 60,000 people yearly infected with schistosomiasis due to contact with infested water, of them 2,000 were acute (Zhang et al, 2002).

Poyang Lake in Jiangxi Province is unique. It is connected to the Yangtze River by a narrow passage. People live behind dikes, whether on high islands in the lake basin or outside the basin. The lake is completely surrounded by dikes, so that with the annual floods (beginning in late May or June and ending in October or November), the lake fills up like a bathtub. During high flood season, the lake is an inland sea available only to fishermen. When the flood subsides, the lake loses as much as 75% of its water, exposing vast flat marshlands. These marshlands constitute a major area of endemicity for schistosomiasis. The marshlands are used for grazing cattle. The epidemiology of schistosomiasis in the Poyang Lake has four unique features. First, cattle are considered to be responsible for more than 85% of the transmission from snails to humans in the lake basin (Guo et al 2003). Second, there are no snails living outside the lake basin behind the dikes. Third, all transmission occurs in the lake basin. Finally, the annual floods drown snails, and presumably the life cycle of the snails is reduced to 1 year or less (Zhang et al, 1996). Most reproduction must then occur in the spring, when the soil temperature rises above 10~C (March or April, depending on the year). The very young snails can withstand the flood and live as aquatic snails.

During the 10 years prior to implementation of the project, control of schistosomiasis in hilly and mountainous endemic areas had been further consolidated and developed through adopting the successful method of “snail control as the main measure in combination with chemotherapy for inhabitants and livestock”. High endemic villages (Prevalence>15%) were reduced from 241 to 90 villages, and medium endemic villages (prevalence between 3-15%) were reduced from 777 to 495 villages (Lin et al, 1999). However, in marshland and lake regions, area of snail habitats is very wide and prevalence factors quite complicated. Some methods such as building embankments and elimination of snails by molluscicide, which were quite effective in the past, cannot be adopted again now because of some negative impacts on the environment. Effective chemotherapy can reduce human infection rate and intensity of infection quickly. However, it is difficult to interrupt the transmission in these areas. According to statistics in 2001, 100,000 chronic cases were estimated, 10,000 bovines with schistosomiasis and about 700 millions m2 snail habitat, more than 80% located in Poyang Lake region (Figure 4). And the re-infection rate is about 12-24%, and new-infection is about 5 –12 % in high endemic areas. It was 35% in villages where prevalence was at the high level in island of Poyang lake region (Zheng, 1999). There are 148 acute case occur in 2002.

After 10 years of morbidity control under the World Bank Loan Project, the prevalence of the residents had clearly reduced, especially in lake regions (Chapter 4). But there are still facing some problems, including 1) the compliance of mass chemotherapy, some results show the coverage of mass chemotherapy in high endemic areas was reduced due to yearly mass chemotherapy (Chapter 10). 2) schistosomiasis transmission still exists in most of the marshland and bovines are a very important transmission source (Chapter 8 and 9). 3) environmental change and funds for schistosomiasis control were reduced after the biggest project (Chapter 4 and 5).

It is clear that large scale chemotherapy can considerably reduce infection rates. Even if encouraging short term results have been obtained, we are still far from a satisfying long-term solution. If we stop mass chemotherapy for 1 or 2 years, prevalence would rise again. As long as transmission continues, mass or selective chemotherapy will have to be repeated indefinitely.

To overcome these problems the following activities are to be implemented in the future: 1) continuing the activities on strengthening control program for morbidity control strategies in high endemic areas, and maintain and consolidate the achievements (Chapter 6); 2) strengthening the epidemiological surveillance in different types of endemic regions especially for lake regions in order to understand the changes of transmission and prevalence in time and provide reliable information for decision making (Chapter 14); 3). strengthening scientific research and accelerate field applications (Chapter 7).

In China, although the morbidity control was carried out for more than 20 years, the total number of infected persons was about 820,000 and 90 million persons were at risk of the infection, and the areas of snail habitats were 3.436 billion m2. After the World Bank Loan Project, the prevalence reduces clearly. However, the re-infection rate and new-infection is very high in high endemic areas every year especially in lake region with flooding. It is easy to spread the snail and local residents have more chance to get infection. While the most of the areas are maintain a low prevalence situation, disease surveillance and snail survey are heavy work. In order to maintain and consolidate schistosomiasis control, it should be continue the strategy of morbidity control in China. GIS/RS can apply in identification of snail habitat and map the high risk areas for mass chemotherapy before making a schistosomiasis control programme. We also can use GIS/RS to find new areas with snail habitat and high potential risk areas, such as Three Gorges areas.

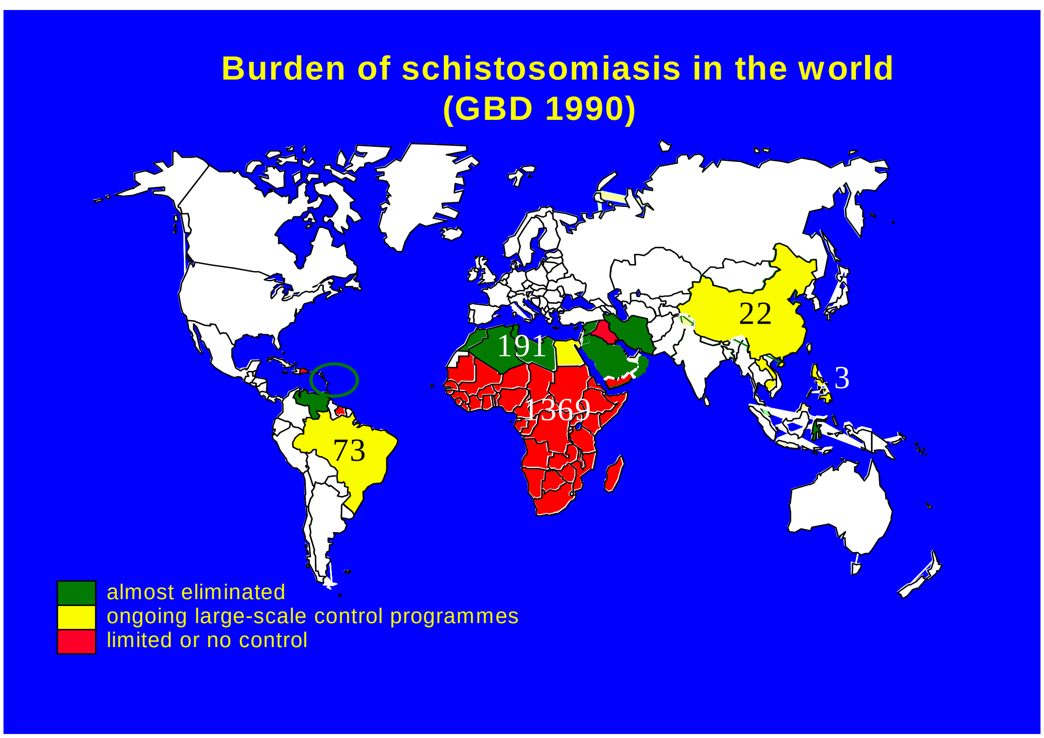

Figure 1 Burden of schistosomiasis in the world (GBD 1990) (WHO, 2002)

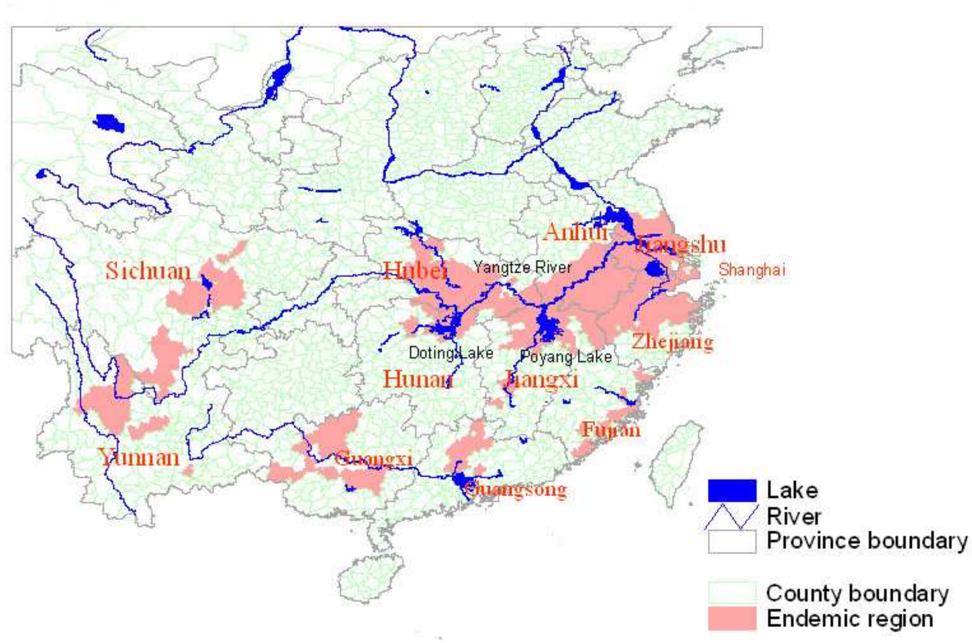

Figure 2 Regional distribution of schistosomiasis before the 1950s in China

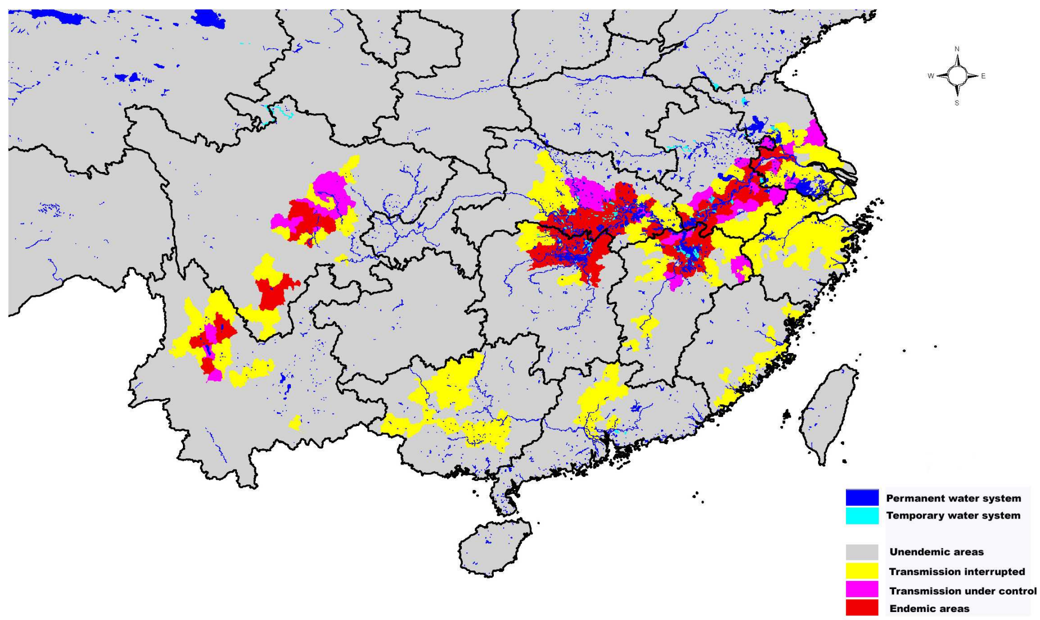

Figure 3 Schistosomiasis regional distribution in the south of China in 2000

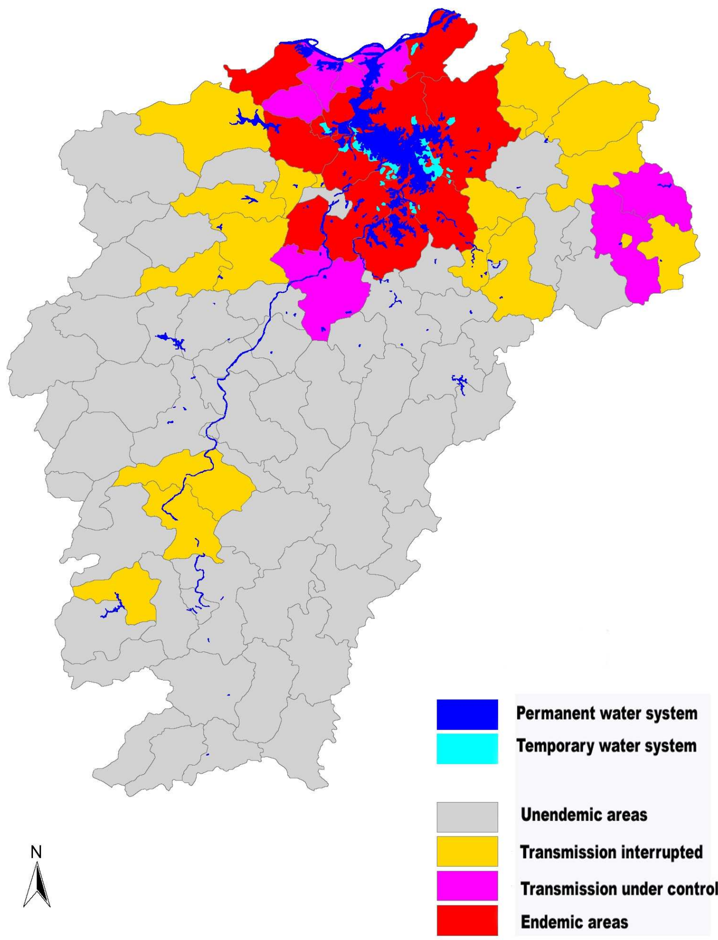

Figure 4 Prevalence of schistosomiasis in Jiangxi province (2000)

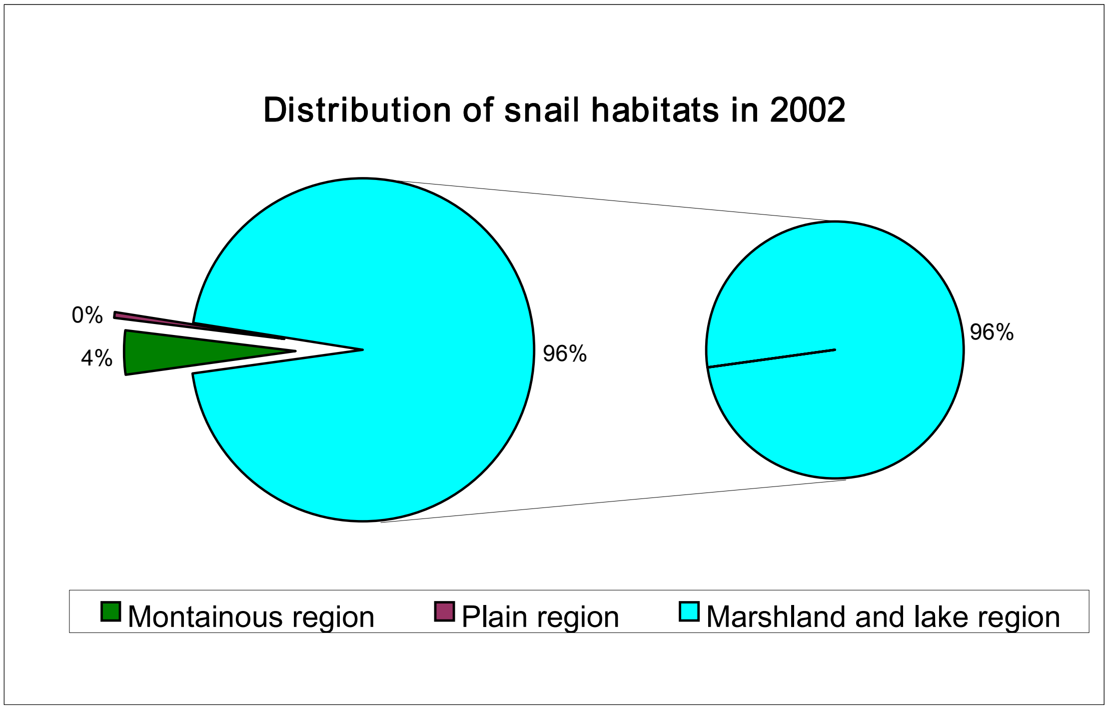

Figure 5 The distribution of snail habitats in 2002

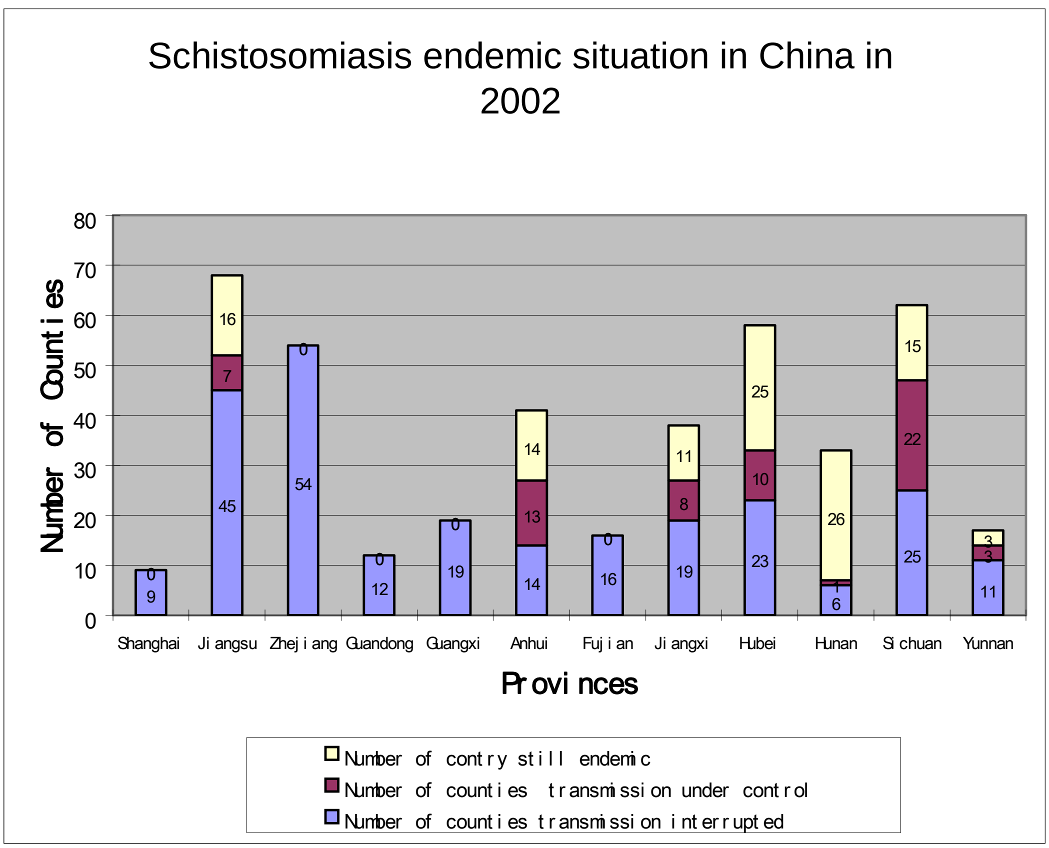

Figure 6 Endemic counties that have achieved the transmission interruption after 40 years control programme.

2 Rationale

2.1 Character of *Oncomelania* in China

There are 96.3481 million person living in schistosomiasis endemic areas in China. Snail habitat areas were 3.466 billion square meters. 94.5% (3.276 billion square meter) snail habitats were in the marshland areas and 4.450% (154 million square meter) in the mountainous and hilly areas and 1.05% (36.5 million square meter) in the plain areas (Guo, 1999). Studying the snail distribution and schistosomiasis transmission rule has very important significant for shaping the strategy of schistosomiasis control. Poyang Lake in Jiangxi province is unique. These marshlands constitute a major area of endemicity for schistosomiasis. There is very typical ecology of *Oncomelania* in Poyang lake region. “No grass no snail”. There are many factors influencing the snail distribution, especially elevation, flooding and vegetation. In general, there are no snail habitats in places that are submerged either less than one month or more than 8 months. There are few snail found in places submerged between 6-8 months. A high density of snail is in areas submerged between 4-5 months. There is abundant vegetation in these areas. In other words, there is a very close relationship between snail distribution and elevation of marshland. Most of the snail habitats are between the 14 to 17 meter elevations in Poyang lake region.

2.2 Remote Sensing as a Landscape Epidemiological Tool

Remote sensing promises to bridge the gap between intensive ecological research and better planning and management of landscapes (Jones et al, 1988). Two distinct advantages of remote sensing for environmental studies are that (1) observer interference is prevented because of the large distance between the sensor and the object; (2) regional or even global measurements can be done repeatedly and (there is a wide variety of spectral ranges and sensors available to provide remotely sensed data (Lulla and Mausel, 1983)

Determining the meaning and validity of remote sensing data requires familiarity with the ecosystem that is being measured, along with a basic understanding of the matter-energy relationship manifested in the remotely sensed data (Jones et al, 1988). Four kinds of ecological inquiry are amenable to remote sensing techniques

(Jones et al, 1988): (1) inventory and mapping of resources, (2) quantification of environmental characteristics, (3) describing the flow of matter and energy in the ecosystem, and (4) evaluating change and alternative solutions for ecosystems management.

The landscape epidemiological approach to the study of disease is based on the identification of environmental factors that determine the temporal and spatial distribution of both vectors and disease (Pavlovsky, 1966; Meade et al., 1988). Factors such as elevation, temperature, rainfall, and humidity influence the presence, development, activity, and longevity of vectors, as well as the development of schistosoma parasites within vectors. Vegetation type and distribution are also determined by these variables and influence vector populations as well. Therefore, we can hypothesize that vegetation as expressed by landscape elements can be used to predict the distribution and abundance of certain vector snails.

The 1990 International Conference on Applications of Remote Sensing to Epidemiology and Phraseology serve to illustrate the diversity of potential remote sensing applications in vector surveillance and control programs. Successful application of remote sensing technology depends on the ability to I) extrapolate measurements made at a local level to a regional or global scale, 2) formulate and test new research hypotheses, and 3) develop near-real time models to predict the spatial and temporal patterns of vector populations and disease transmission risk.

2.3 Rapid Assessment of Schistosomiasis Risk

2.3.1 Snail Habitat

The area over which schistosomiasis is endemic depends on the distribution and population of the host snails, which in turn it depends on geographical and environmental characteristics such as vegetation, land-use patterns, surface waters, quality and humidity of the soil, and climatic changes. The four main factors of schistosomiasis transmission, vegetation, wetness, soil temperature and elevation can be extracted by remote sensing. By hypothesizing environmental characteristics, as expressed by landscape elements, we can predict the distribution and abundance of certain vector snails. The resolution of a Landsat 7 image is 30 X 30 m. This is sufficient to assess large areas such as the 10,000 square meter marshlands in Poyang lake areas. However, it is too low to recognize snail habitats in small rivers and channels. In this thesis, we develop a model of rapid identification of snail habitats in Poyang lake by analysing remotely sensed satellite images. The model has been validated in the field. We also identify the snail habitat within the micro-environment, including pH value and other microelement.

2.3.2 People's Behaviour Including Water Contact

We used mass chemotherapy in high endemic where the prevalence is more than 15 %, and selective chemotherapy in medium and low endemic areas where the prevalence is less than 15% during the World Bank Loan Project. Many studies show that it is not reasonable to expect compliance from residents who have been treated frequently. Even residents who never contacted infective water were treated. One year later none of the serological diagnosis can detect re-infection after treatment. In this study, we will use the mode of water contact to analyse the frequency of water contact and water contact score. The aim is to record patterns of water contact to detect individuals at risk, and to set an indicator to make certain the individual target of treatment as well as to assess the prevalence in these areas.

2.3.3 Distance Between Villages to Transmission Sites

Most studies in Poyang Lake region shows that there is a relationship between prevalence and distance between villages to transmission sites. In this study we apply our rapid identification of snail habitats model to estimate the prevalence of *S. japonicum* in the villages of our study area by measuring the distance of each village from the transmission sites from the transmission sites predicted by the model. This approach enable us to identify areas where schistosomiasis control strategies (i.e. mass chemotherapy or selection chemotherapy) should be applied.

3 Goal, Objectives and Underlying Hypotheses

The overall goals of this thesis are:

To summarize the Chinese experience in schistosomiasis control and to map snail habitat and high transmission areas in the Poyang lake region. It is also to explore and model the relationship between prevalence and distance from village to high transmission sites to predict high potential risk transmission areas.

Objective 1

Describe and analyse the experience of schistosomiasis control in China during the past 10 years.

Objective 2

Describe the different characteristics of snail habitats around the villages, and relate them to environmental factors which can be extracted by Remote Sensing.

Objective 3

Estimate the prevalence of schistosomiasis among residents and bovines by modelling water contact patterns and distance between transmission sits and human habitats, mainly via (1) comparing RS images and setting up a transmission model for human infection in Poyang Lake region, and (2) predicting and validating the potential of high transmission in Poyang lake region.

Hypotheses

1. Remote Sensing cannot differentiate the characteristics of snail habitat with regards to vegetation, humidity and temperature.

2. There is no relationship between infection rates and water contact and distance from village to high transmission sites.

Strategy of study

In order to test both hypotheses, the following steps have been used:

- analysis of the experience of schistosomiasis control in China during the past 10 years
- analysis of *S. japonicum* transmission patterns in pilots villages with high endemicity
- description and analysis of snail habitats by RS and conventional sampling techniques,
- description of the transmission dynamics by analysing the water contact patterns,
- development of a transmission model of schistosomiasis by combined analysis of ground level pictures of transmission sites, a GIS database of key features, and RS images,
- estimation of the predictive potential of the transmission model in other areas.

These steps will be pursued in three phases:

Phase I: Map snail habitat and high transmission areas in Poyang Lake region

Phase II: Explore the relationship between snail habitat and Thematic Mapper (TM) image data.

Phase III: Explore the relationships between prevalence and distance from village to high transmission sites and water contact and set up a model to predict high potential risk transmission areas.

Structure of the thesis

The studies described in the present thesis include the description of schistosomiasis control in China, in particularly the strategy, achievements and results on morbidity of the World Bank Loan project on schistosomiasis control during the past 10 years, including some field activities and cost estimates (Chapters 4, 5, 6 and 7). Features of the schistosomiasis epidemiology in Poyang lake such as the distribution of the snail habitats, the characteristics of schistosomiasis transmission, the role of buffaloes in transmission patterns and the mass chemotherapy compliance of residents in high endemic areas are given in Chapters 8, 9, 10 & 11.

New approaches and techniques which have impacted the strategies of schistosomiasis control in China are discussed in Chapter 12. Chapter 13 presents a GIS and RS application on identifying bovine grazing areas which are suitable for snails. Finally, we have developed a new model using GIS and RS technologies for identifying snail habitats in the Poyang lake area. Preliminary validation revealed excellent accuracy of the model in predicting the presence of *Oncomelania hupensis*. The model has been further applied in estimating the overall prevalence of *S. japonicum* in the villages in the Poyang lake area. A description of the model and its applications are given in Chapter 14. Discussion and concluding remarks are included in Chapter 15.

4 Schistosomiasis Control in China: The Impact of a 10-year World Bank Loan Project (1992-2001)

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4.1 Abstract

China has been carrying out large-scale schistosomiasis control since the mid-1950s, but in the early 1990s, schistosomiasis was still endemic in eight provinces. A World Bank Loan Project enabled further significant progress to be made during the period 1992–2001. The control strategy was focused on the large-scale use of chemotherapy — primarily to reinforce morbidity control — while at the same time acting on transmission with the ultimate goal of interrupting it. Chemotherapy was complemented by health education, chemical control of snails and environmental modification where appropriate. A final evaluation in 2002 showed that infection rates in humans and livestock had decreased by 55% and 50%, respectively. The number of acute infections and of individuals with advanced disease had also significantly decreased. Although snail infection rates continued to fluctuate at a low level, the densities of infected snails had decreased by more than 75% in all endemic areas. The original objectives of the China World Bank Loan Project for schistosomiasis control had all been met. One province, Zhejiang, had already fulfilled the criteria for elimination of schistosomiasis by 1995. The project was therefore a success and has provided China with a sound basis for further control.

Key words: Schistosomiasis japonica/epidemiology/drug therapy/prevention and control; Program evaluation; World Bank; China

4.2 Introduction

Schistosomiasis caused by Schistosoma japonicum has long been a major public health problem in China. Sustained control efforts had reduced the number of infected people from 11.8 million in the 1950s (Chen et al. 1999) to 1.6 million in 1989 (DEDC, 1993). Four out of 12 provinces had eliminated schistosomiasis by that year, but the disease was still endemic in 240 counties in eight provinces, and 44 million people were estimated to be at risk. *Oncomelania* snails were still present in numerous areas covering a total of 3.6 billion m^2, and the animal reservoir of *S. japonicum* — thought to play a major role in transmission — was still considerable. Approximately 0.2 million cattle and buffaloes were estimated to harbour the infection. Schistosomiasis control therefore faced a serious challenge at the end of the 20th century. There was a consistent gap between the available funding and the financial resources required to make further progress. In response to this situation, the Chinese Government obtained a long-term World Bank loan to boost schistosomiasis control.

The objective of The World Bank Loan Project (WBLP) for schistosomiasis control was to boost morbidity control according to the strategy recommended by the WHO (WHO, 1993; OEDC, 1996) while, at the same time acting on transmission with the ultimate goal of interrupting it. The main control tool was large-scale chemotherapy; this was complemented by health education, chemical control of snails and environmental modification where appropriate. The specific operational targets set were as follows:

- to reduce the prevalence of infection in humans by 40%;
- to reduce the prevalence of infection in cattle and buffaloes by 40%; and
- to reduce the snail infection rate and the density of infected snails by at least 50%.

4.3 Materials and Methods

The project area covered eight provinces containing 219 counties in which schistosomiasis was still endemic in 1992. Three operational strata were defined on the basis of disease prevalence in humans as recorded during a nationwide epidemiological survey conducted in 1989 (DEDC, 1993), and different control strategies were applied in each of these strata. Large-scale chemotherapy was the main control tool used to reinforce morbidity control in areas of high endemicity (i.e. prevalence >15%) and medium endemicity (i.e. prevalence between 3% and 15%), whereas in areas of low endemicity (i.e. prevalence < 3%) the transmission control component was reinforced by environmental management. The technical approaches are described below.

4.3.1 Chemotherapy in human populations

In areas of high endemicity, all individuals between 6 and 60 years old were given yearly treatment. In areas of medium endemicity, half of the residents were screened by examination of a stool examination (using the Kato–Katz technique) or a serological test (enzyme-linked immunosorbent assay (ELISA), circumoval precipitin test or indirect haemagglutination test) every year (i.e. each person was tested every other year) and those with positive results were treated. In areas of low endemicity, all 7–14-year-old children were screened in the same way as in areas of medium endemicity every other year and treated if their results were positive. The treatment in all areas consisted of a single dose of praziquantel, at a dosage of 40mg/kg body weight.

4.3.2 Chemotherapy in livestock

In areas of high endemicity, all cattle and buffaloes were treated once a year without preliminary screening. In areas of medium endemicity, approximately one-third of cattle and buffaloes were treated once a year, primarily those that had been pastured on areas with transmission potential. In areas of low endemicity, cattle and buffaloes imported from other provinces in which schistosomiasis was endemic and those under 2 years of age pastured on snail-infested land were examined and treated with praziquantel if infected.

4.3.3 Snail surveillance and control

In areas of high endemicity of schistosomiasis, random snail surveys were carried out in approximately 40% of the snail infested areas each year. Mollusciciding with niclosamide, at a concentration of 2 ppm by immersion or 2 g/m^2 when sprayed, was carried out in areas where infected snails were found. In areas of medium endemicity, yearly snail surveys were carried out around villages and in half of the areas with high transmission potential. Wherever infected snails were found, molluscicide treatment was carried out. In areas of low endemicity, 50% of the snail habitats were surveyed annually and areas with infected snails treated with niclosamide. Chemical molluscicide treatment in all the above-mentioned localities was generally done annually. Environmental modification was primarily carried out in areas of low endemicity with the aim of permanently interrupting transmission. Environmental modifications included the digging of new ditches and filling of old ones, lining of irrigation canals with concrete, and the alteration of sluice gates to prevent snails from spreading into other sections of an irrigation system (e.g. by adding a sedimentation pool) (Chen et al., 1999).

4.3.4 Health education

Healthy behaviours were encouraged through health education. The tools used included comic-style booklets, radio and television spots and other innovative techniques. By the end of the WBLP, more than 80% of residents in areas in which schistosomiasis was endemic were expected to understand the aim of schistosomiasis control; more than 70% of the target population were expected to modify their behaviour, reduce contact with infested water or adopt preventive measures (such as the use of repellents or the impregnation of clothes with niclosamide) if contact with infested water was inevitable; and more than 90% of the target population were expected to fully cooperate with anti-schistosomiasis professionals in the screening and/or treatment activities.

4.3.5 Disease surveillance

To monitor epidemiological changes and trends during implementation of the programme, a system was set up in which 3% of villages in areas with high endemicity were randomly selected as surveillance sites every year, and 1% of villages in areas with medium and low endemicity. On the basis of the surveillance data collected (on humans, livestock and snails), the level of endemicity in the villages was regularly reclassified (every 1–2 years), and the control strategy adapted accordingly. Once a township (including from several to 20 villages) had reached a low level of endemicity, it was also regularly evaluated against a different set of criteria, aimed at determining whether it had reached the stage of "transmission control" or "transmission interruption" (Chen et al., 1999; OEDC, 1996). Monitoring of the implementation process was also part of the surveillance system.

4.3.6 Training and operational research

Regular training courses were provided for schistosomiasis control staff and programme managers to improve their technical and management skills. Operational research was guided by a joint research management committee (JRMC), involving both Chinese and foreign experts. The responsibilities of the JRMC were to define the priorities for operational research, to gradually increase the research capacity of Chinese professionals working in schistosomiasis control, to check the quality of research proposals and approve funding for them, and to monitor progress in research (Yuan et al., 2000).

4.4 Results

The total investment in schistosomiasis control by the WBLP has been 890 million RMB yuan (approximately US$ 152 million), of which 416 million RMB yuan (US$ 71 million) was a loan provided by The World Bank and 474 million RMB yuan

(US$ 81 million) came from counterpart funds provided by the Chinese Government. The WBLP started in eight provinces in 1992, was finalized in five of them (Anhui, Jiangsu, Jiangxi, Sichuan and Zhejiang) at the end of 1998, and continued until the end of 2001 in the three remaining provinces (Hubei, Hunan and Yunnan). However, the five provinces that completed the project in 1998 continued to carry out schistosomiasis control with their own funds according to the operational plan set out by the WBLP.

During the 10-year implementation period of the WBLP, more than 63 million people were screened, and almost 19 million treatments were given, both in mass chemotherapy and selective treatment campaigns. A total of 1.7 million cattle and buffaloes were screened and those infected were treated with praziquantel. An additional 2.2 million animals received mass chemotherapy. In 1998, when the WBLP came to an end in five of the eight provinces, the number of infected people in China had been reduced by 50% from 1.7 million (in 1992) to 874 500 (Table 1). This number had further decreased to 828 000 in 2001. The average number of patients diagnosed per year with acute schistosomiasis decreased from 6386 during the period 1989–91, to 1093 cases during the period 1996–2000, despite severe floods in 1998–99. In 2001, only 573 acute cases were reported (Chen et al. 2002). The number of patients with advanced hepatosplenic disease decreased from 55 000 in 1989 to 25 664 in 2001, a decrease of 53.3% (Chen et al. 2002) (Figure 9). All other operational targets appeared also to have been reached in 2001: the percentage of humans who had positive results of stool examination had decreased by 55%, the number of infected cattle and buffaloes by 55% and the percentage of animals with positive results of stool examination by 50%. The density of infected snails in areas of high, medium and low endemicity had decreased by 76%, 90% and 87.5%, respectively (Table 1).

Although the density of infected snails had substantially decreased, the total area of snail habitats fluctuated during the period 1992–98, from 3.3 billion m^2 to 3.5 billion m^2 (Wang et al., 2000). In 2000, the percentage of humans and animals with positive results of faecal examination had increased to 4.15% and 3.36%, respectively, following the 1998–99 floods (Chen et al., 2001).

Approximately 9.6 billion m^2 of snail habitats were regularly surveyed and snail control was carried out on an area of 3.9 billion m^2. Environmental modification projects were carried out on 1.1 billion m^2, and the remaining area (2.8 billion m^2) was regularly treated with molluscicide. Between 1996 and 2001, a total of 1167 projects for environmental modification (at an estimated cost of between 50 000 and 200 000 RMB yuan each) were carried out. A health education network was established. Various types of video and broadcasting material, information pamphlets, posters, slogans and textbooks were developed and distributed during the project period. The coverage rate for health education in the field of schistosomiasis control was very high in school-age children. In villagers living in areas where the disease was endemic, knowledge about schistosomiasis increased, resulting in decreased contact with infested water and increased individual protection when contact with infested water was unavoidable. As a result of health education, the adherence rate for screening and treatment activities approached 90% (Table 3).

Table 1 The World Bank Loan Project for schistosomiasis in China: operational indicators 1992-1998.

Item	In 1992	In 1998	Reduction rate (%)
No. infected Persons	1733981	874515	49.57
Positive rate (%) in fecal examination	6.93	3.14	54.69
No. infected bovine	104764	47115	55.03
Positive rate (%) in fecal examination in bovine	6.38	3.17	50.31
Density of infected snails in areas with			
high endemicity	0.0078	0.0019	75.64
medium endemicity	0.0060	0.0006	90.0
low endemicity	0.0008	0.0001	87.5

In a total of 3669 villages under surveillance, 1 445 800 people and 154 907 cattle and buffaloes were randomly screened, and of those screened 62 978 people (4.3%) and 6439 animals (4.1%) were found to be infected. A total of 6 720 075 quadrats (0.1m^2 each) of land potentially inhabited by snails were surveyed. A total of

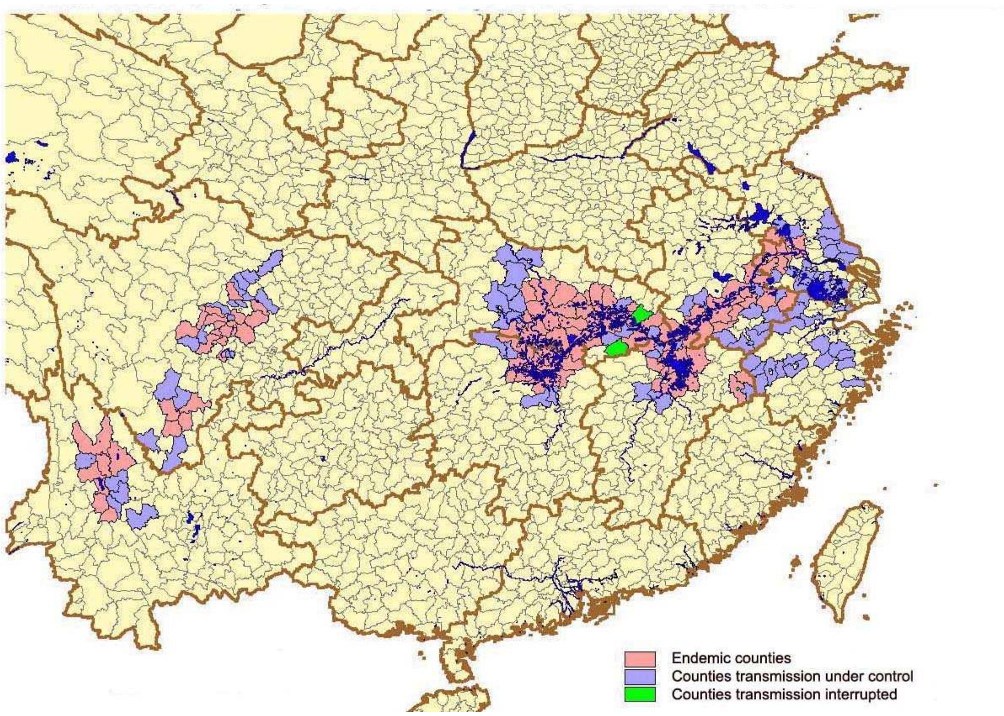

Figure 7 Distribution map of the World Bank Loan Project counties and their endemicities before the project

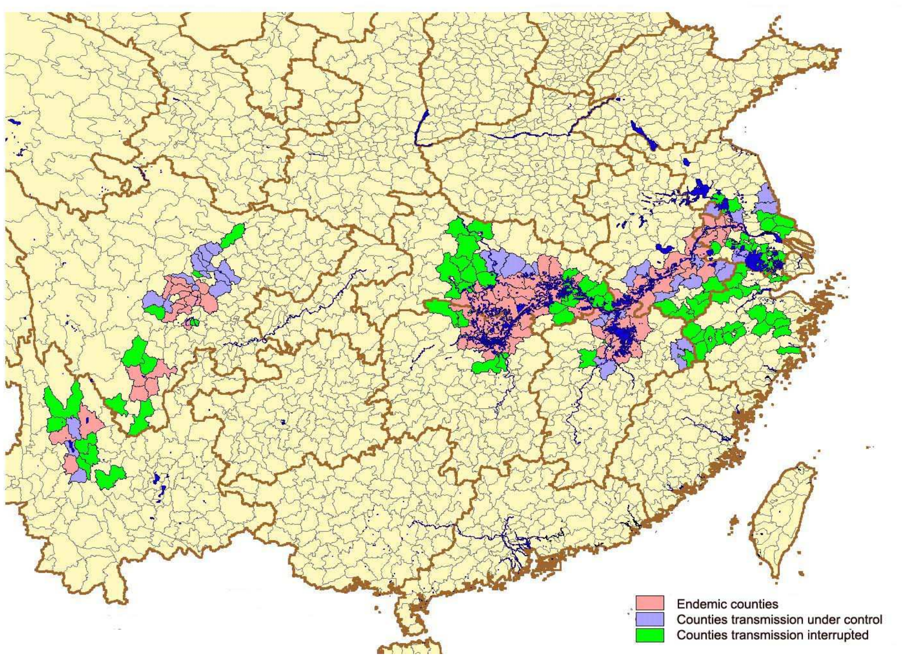

Figure 8 Distribution map of World Bank Loan Project counties and their endemicities at the end of the project

3 669 720 snails were collected and dissected, and 9637 (0.26%) were found to be infected. Snail infection rates remained below 0.76% over the whole duration of the project, with slight year-to-year fluctuations, presumably reflecting the varying intensity of yearly flooding or due to sampling variation (Fig. 10). The density of infected snails decreased sharply in areas of high and medium endemicity during the first 5 years of implementation of the control programme, and was thereafter maintained at a level below 0.003/0.1m^2 (Fig. 11).

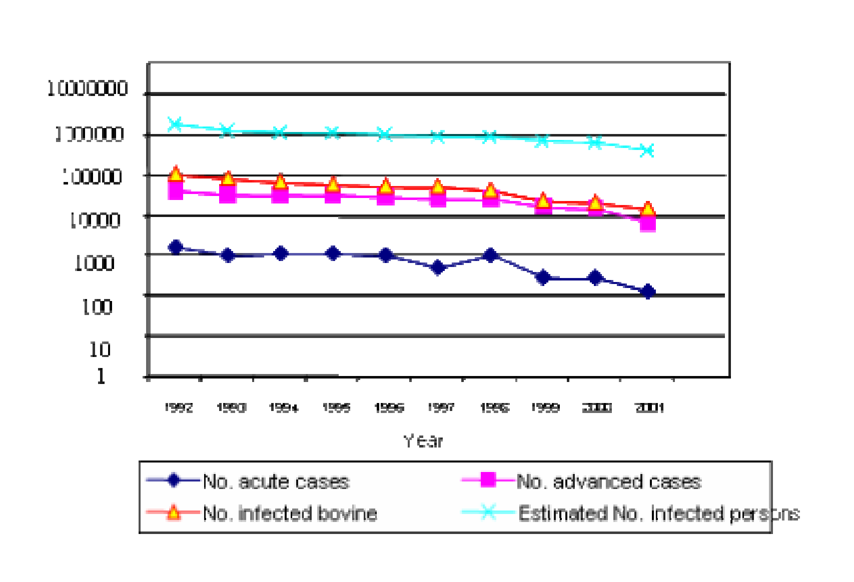

Figure 9 Changes in the number of infected persons and bovines from 1992 to 2001

The number of villages and people in the three epidemiological strata, as well as the average prevalence of schistosomiasis in each stratum, changed substantially over the project period, with a gradual shift towards a lower level of endemicity (Table 2). Villages with a high level of endemicity were only reclassified as "medium" once the transmission was judged to have permanently decreased.Out of a total of 409 endemic counties in the 1950s, 238 had reached the criteria of transmission interruption, 56 the criteria of transmission control, and 115 were still considered to be endemic in 1999 (Jiang et al., 2002). During the period of the WBLP (1992–2001), out of a total of over 200 countries initially involved, 47 had met the criteria of transmission control and 82 had met the criteria of transmission interruption (Figure 7 and 8). Zhejiang Province had reached the target of elimination in 1995 (OEDC, 1996). Although substantial progress in transmission control was made during the WBLP period, the potential for transmission remains considerable in counties around the Dongting and Poyang Lakes, in the Yangtze River Basin, and in some mountainous areas in the provinces of Sichuan and Yunnan (Jiang et al., 2002).

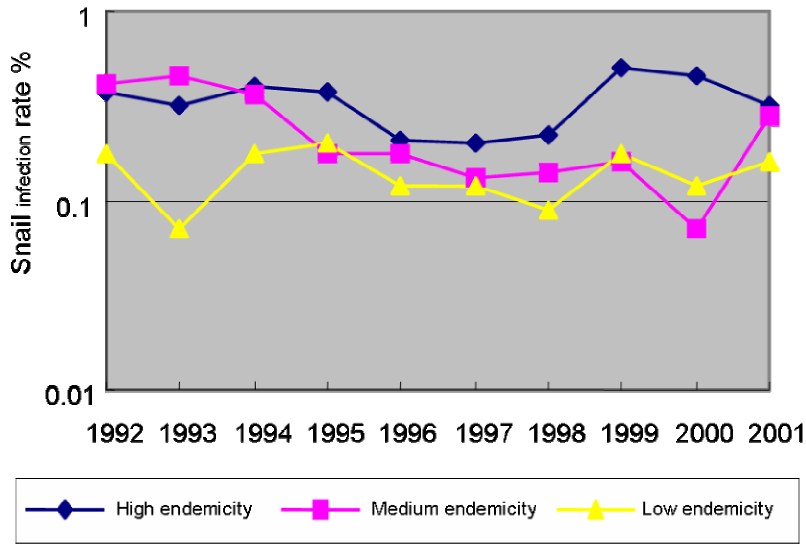

Figure 10 Changes in snail infection rate in the three strata between 1992 and 2001

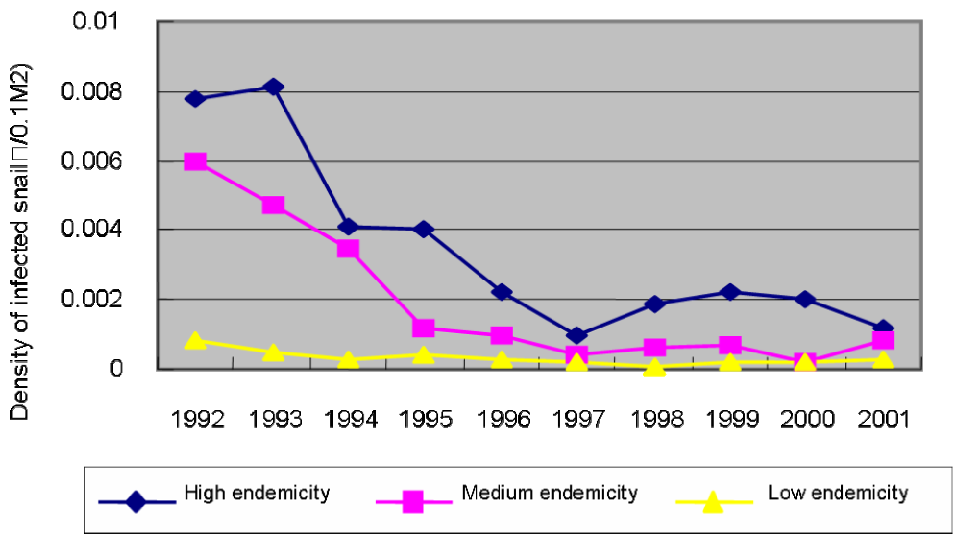

Figure 11 Changes in the density of infected snails from 1992 to 2001

Professional training courses were held on topics such as epidemiology, control strategies, health economics, social medicine and communication strategies, immunology and immuno-diagnosis, and improving computer skills. Between 1992 and 2001, 7 160 501 trainees participated in such courses. In order to improve the capacity of young researchers to carry out operational research and develop research proposals, special training was also provided in study design and research methodology.

Table 2 Population data and human infection rates in the different epidemiological strata 1992-1998

Year	1992			1998		
Stratum	High	Medium	Low	High	Medium	Low
No. villages	4058	9519	26834	2552	6759	30850
Population (million)	2.656	9.806	32.306	1.520	7.391	44.584
Infection rate (%)	17.06	6.51	1.23	8.52	3.42	0.64

Over 37 million RMB yuan (about US$ 5.3 million) has been provided for operational research by the JRMC, complemented by 21 million RMB yuan (about US$ 3 million) in counterpart funds provided by the provinces taking part in the project. From 1992 to 1998, more than 800 research proposals were submitted to the JRMC, of which 245 were granted funding and provided valuable information for improving control activities. Particular achievements were made in the field of fast and easy diagnostic techniques, and the development of prophylactic drugs (artemether and artesunate) against schistosomiasis. A total of 1083 papers were published in scientific journals.

Table 3 Knowledge, attitude and behaviour changes on schistosomiasis control of targeted people in pilot areas

Items of Investigation	No. followed	Before intervention in 1994		After intervention in 1996	
		No. passed	%	No. Passed	%
Awareness of schistosomiais	500	232	46.4	498	99.6
Decrease in contact with infested water	500	234	66.8	494	98.8
Willingness to receive chemotherapy	500	317	63.4	497	99.4
Owners'willingness to receive treatment for their bovine	500	232	46.4	498	99.6

All of the project data were collected in the peripheral project offices, and systematically aggregated both at the district and provincial level. A computerized information management system was set up from the central level down to the provinces.

4.5 Discussion

The 10-year China WBLP for schistosomiasis control was a success. The large-scale use of chemotherapy has facilitated morbidity control in humans (WHO, 1984; WHO, 1993; WHO, 2004). The number of cases of acute schistosomiasis and of hepatosplenic disease — good indicators for the prevailing morbidity due to schistosomiasis — have all substantially decreased. Moreover, it is believed that the systematic treatment of livestock has substantially contributed to the reduction of transmission. The relative contamination index in cattle and water buffaloes may be as high as 70–90% in China (Chen et al., 1993).

The targets set at the beginning of the WBLP have been reached or exceeded. The estimated number of people infected with schistosomiasis had decreased by over 50% by the end of 2001. The prevalence in humans and livestock had also decreased by over 50%. Although the snail infection rates have continued to fluctuate at a low level, the densities of infected snails in the different epidemiological strata had all decreased by more than 75% by the end of the project. One province that took part in the project, Zhejiang Province, was able to fulfil the national criteria for schistosomiasis elimination during the course of the project. Furthermore, many counties have fulfilled the criteria for interruption of transmission.

The achievements were severely challenged by two successive years of heavy flooding (1998–99) in the Yangtze River basin. However, although some impact on schistosomiasis was noted, it was quite limited.

The achievements of the WBLP are not limited to an improvement in epidemiological indicators of schistosomiasis. The capacity of project managers and scientific institutions has also been strengthened, and the technical expertise of the professionals involved has been improved.

Although a sound basis for schistosomiasis control has been laid, the disease is far from being eliminated in China. Considerable transmission of schistosomiasis persists in the five provinces situated around the Yangtze River Basin and its lakes, as well as in two mountainous provinces. Difficulties in stabilizing the water level in the Yangtze River Basin, the complicated environmental topography of the mountainous areas, and the lack of economic development in some of the remaining areas of endemicity, all contribute to the continuing challenge of schistosomiasis control. Because of the mobility of populations and the frequent trade of livestock, some fluctuation in the prevalence of schistosomiasis is to be expected. During the WBLP period, large-scale use of chemotherapy kept the prevalence and incidence low. However, since the end of the WBLP, the funding for schistosomiasis control has been reduced. With less funds, it will be difficult to make further progress in the control of schistosomiasis in China. Furthermore, as the project paid limited attention to control of the *Oncomelania* snail, the environment for its transmission has not been changed substantially. A schistosomiasis control programme mainly based on chemotherapy with health education can certainly reduce prevalence and morbidity, but the control effect cannot be sustained. This has been seen following the control projects in Brazil and in the Lao People's Democratic Republic. In Brazil, the use of chemotherapy had greatly reduced morbidity due to *S. mansoni* infection from 1977 to 1994, and in the Lao People's Democratic Republic, the prevalence of *S. mekongi* decreased sharply after repeated chemotherapy with praziquantel in the Khong District, i.e. from 40% in 1989 to only 1% in 1997 (WHO, 1999). However, as the chemotherapy campaign has been relaxed, prevalence has increased again in both Brazil and the Lao People's Democratic Republic.

For the sustainable control of schistosomiasis, the experiences of China and Japan indicate that at the same time as other control approaches are used, the control of the intermediate host snail (mainly with environmental modification complemented with molluscicide treatment) should be given priority (Chen et al. 1999; Tanaka et al., 1997). China's experience in elimination of schistosomiasis in large areas in five provinces with sustainable effect during the past half decade has repeatedly confirmed this. However, this important point was not sufficiently addressed in the planning and execution of the WBLP. This is a lesson that should be taken into account. It has been noted that since the end of the WBLP, as the commitment to schistosomiasis control has weakened, the prevalence (especially the number of acute infections) had increased again in 2003 (unpublished data from the Chinese Ministry of Health). This is because the basis for the transmission, i.e. the snail habitats, has not been changed greatly through the implementation of the WBLP. The "God of Plague" has slowly returned to China, a cause of great concern for the Government of China, and a new project for sustainable control has been formulated that includes chemotherapy, health education and transmission control. This new project stresses the need for environmental sanitation, mainly focusing on snail control, by reducing large areas of snail habitats in the forthcoming decade. It can be expected that the achievements of the WBLP, China's own wealth of experience on schistosomiasis control, the significant attention paid by the Government combined with the rapid development of China's economy, will ensure a bright future for schistosomiasis control by eliminating the disease from more areas, county by county, and province by province.

Acknowledgements

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5 Morbidity Control of Schistosomiasis in China

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5.1 Abstract

After reviewing the schistosomiasis control program in China with a focus on the socio-economic impact on schistosomiasis endemicity, we introduce the promotion process of morbidity control strategy undertaken before and during the World Bank Loan Project (WBLP) on Schistosomiasis Control. We analyzed the data derived from case study of morbidity control for schistosomiasis, and evaluated the efficacy of chemotherapy. It is suggested that appropriate drug treatment declines worm burden and the intensity of infection as well as prevalence, but chemotherapy alone can hardly reduce the transmission because zoonotic *Schistosoma japonicum* infection has a great impact on the transmission of the disease. Therefore, the strategies in different (high, medium, and low) transmission areas during the maintenance stage were put forward in consideration of challenges in national control program in the future.

Key words: Morbidity control, *Schistosomiasis japonicum*, Case study, Chemotherapy, China

5.2 Introduction

In China, schistosomiasis due to *Schistosoma japonicum* is a big health problem. Great suffering and premature death among people existed for centuries. More than 100 million people were at risk of the infection in southern China (Chen, 1989; Yuan, 1992). The endemic areas were mainly distributed along the Yangtze River and down to the basin of the Yangtze River including 404 counties/cities in 12 province level (Fig. 12). Geographically, the northernmost limit of the endemic area is at 33°25' latitude north, the southernmost at 22°42 ' latitude north, the easternmost at 121°45' longitude east, and the westernmost at 99°0 5' longitude east. The high-risk areas are around the middle and lower reaches of the Yangtze River, Tongding Lake and Poyang Lake. Based on epidemiological pattern, the intermediate of the snail ecology in endemic areas, the endemic regions can be stratified into three types, that is plain regions, marshland and lake regions, hilly and mountainous regions.

The schistosomiasis causes severe morbidity resulting in disability and death. Some of endemic areas had had the sad name of 'village without villagers', because most of the residents died from schistosomiasis and the others moved away before the national schistosomiasis control program started. It was also a serious disease for the cattle, pigs and other domestic animals. The intermediate host of *S. japonicum* is an amphibious snail that lives not only in water all the time, so daily activity of the farmers, cattle herding, fishing, grass harvesting in the marshlands along rivers and lakes led to intense water contact, and as a result, to get the infection.

5.3 Schistosomiasis control in China

5.3.1 Achievement of schistosomiasis control

Although China is a developing country, significant gains in health status and diseases control including anti-schistosomiasis have been achieved.

In China, schistosomiasis control has been put as a high priority in disease control. A national leading group for schistosomiasis control was set up since 1955. The leading group was composed of the members of political bureau of Central Committee of Chinese Communist Party (CCCP), ministers of health, agriculture and water resources. In the endemic areas, the special health sectors for anti-schistosomiasis had been set up at the provincial level, station at the county level and community level. These institutions have been fully supported by the governments at different levels.

Health workers in cities and medical schools were asked to work in the rural areas to help the control work.

Combined approaches of snail control, chemotherapy, health education and hygienic movement have been integral components of the control strategy practiced in the country. China has made substantial progress against schistosomiasis through these approaches.

Active community participation in schistosomiasis control plays an important part. Primary health care was extended in the endemic areas through 'barefoot doctor' system.

The person with schistosomiasis was easy to get treatment. In endemic areas, all the cost on schistosomiasis control was parts of the government expenditure. The treatment was usually free of charge for the farmers.

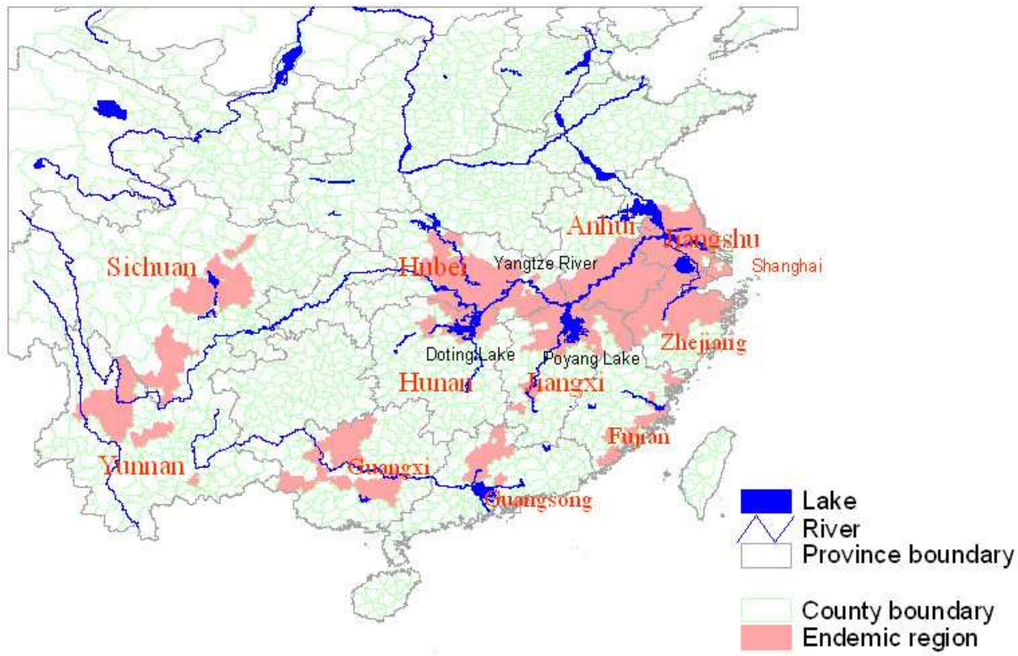

Figure 12 The regional distribution of schistosomiasis before the 1950s in China

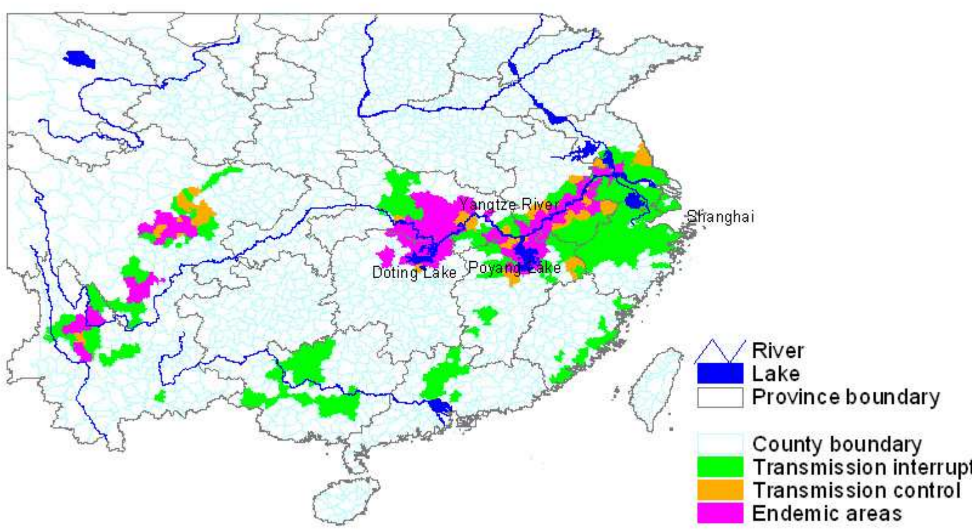

Figure 13 Schistosomiasis regional distribution in 2000 in south of China

After continued efforts over the past five decades, schistosomiasis has been successfully eliminated in the provinces of Guangdong, Fujian and Zhejiang, in the municipality of Shanghai and in the autonomous region of Guangxi. According to the data by the end of 1999, there were a total of 409 counties endemic for schistosomiasis. Among them, 238 counties have reached the criteria of transmission interruption, 56 counties have reached the criteria of transmission control where the prevalence is at a very low level and in remaining 115 counties, the disease is still endemic mainly distributed in the marshland and mountainous regions (Wang et al., 2000) (Fig. 13 and Table 4).

Table 4 Schistosomiasis endemic areas in China and progress since 1999

Province	Formerly endemic population (in 10 000)	Counties in endemic areas	Number of counties transmission interrupted	Number of counties transmission under control	Still endemic
Shanghai	291.66	9	9	0	0
Jiangsu	3576.26	57	35	7	15
Zhejiang	947.09	54	54	0	0
Guangdong	712.74	12	12	0	0
Guangxi	74.37	19	19	0	0
Anhui	589.24	41	14	13	14
Fujian	246.88	14	14	0	0
Jiangxi	403.28	37	19	7	11
Hubei	1354.73	58	20	6	32
Hunan	541.54	29	7	1	21
Sichuan	1581.76	62	25	20	17
Yunnan	134.93	17	10	2	5
Total	10 454.48	409	238	56	115

Data from Department of Diseases Control, Ministry of Health.

5.3.2 The socioeconomic impact on schistosomiasis endemicity during economic reform

The endemic situation of schistosomiasis fluctuated in the 1980s. The data of National Disease Information System showed that the positive rates of stool examination among the residents in the 1980s had increased considerably. For instance, in Hunan Province, stool positive rate from 2.742% in 1980 increased to the 4.834% in 1989; in Hubei Province, stool positive rate from 4.703% in 1980 increased to the 7.355% in 1989; in Jiangxi Province, stool positive rate from 4.616% in 1980 increased to the 8.331% in 1989 (Chen et al., 1990). The national schistosomiasis sampling survey in 1989 showed that the estimated number of the persons with schistosomiasis in the marshland areas was 1.30 millions, making up 79.35% of 1.638 million infected persons in whole country (Zheng, 1992)(Table 5). The endemic areas of high mountain were mainly located in Yunan and Sichuan provinces. The number of infected persons was estimated to be 308 334 in these two provinces (Wang, 1989; Yuan, 1992a,b; Gao, 1993). During 1980s, the acute cases of schistosomiasis in the marshland endemic areas increased yearly. This trend was probably attributed to the change of socioeconomic reform starting from late 1970s. The economic reform changed the governmental budgets for schistosomiasis control that usually came from three levels (county, province and central governments). After the reform, nearly all the budget for schistosomiasis control came from local government. Most of schistosomiasis endemic areas were located in the poor economic zone, and the local government budget was very humited for the control. The resources could not meet the need of schistosomiasis control.

Table 5 Prevalence of schistosomiasis by province estimated from a nationwide sampling survey in 1989

Province	Geography	Infected people	%	Snail-infested area (10^4 m^2)	%
Hunan	Lake regions	341 192	20.83	170 266.04	47.99
Hubei	Lake regions	551 409	33.66	76 106.93	21.45
Jiangxi	Lake regions	272 100	16.61	70 973.17	20.01
Anhui	Lake regions	120 068	7.33	22 495.91	6.34
Jiangsu	Plain and lake regions	15 000	0.92	5940.70	1.67
Sichuan	Mountainous regions	184 934	11.29	6033.93	1.70
Yunnan	Mountainous regions	123 400	7.53	2915.98	0.82
Zhejiang	Plain and hill regions	30 000	1.83	38.41	0.01
Total		1 638 103	100.00	354 771.07	100.00

The other socioeconomic change was the ownerships of land from 'commune' to households, and the communities were no more an economic body again after the reform. Due to the budget problem, the facilities of anti-schistosomiasis supplied usually by the provincial government were moved to the county. Some county anti-schistosomiasis stations only had the budget for personnel and they did not have any more resource to purchase drug and chemicals for schistosomiasis control. The local health facilities and station were encouraged to charge patients for services or to operate the other business to meet the need of the personnel and operational costs.

Accompanying the changes in financial system, the national organization of anti-schistosomiasis system had been reorganized. Before 1986, there was a special national organization on anti-schistosomiasis that was under CCCP. During the economic reform, the national leading group for schistosomiasis control was disestablished and schistosomiasis control was directly under the leadership of the Ministry of Health. A new bureau, the Bureau of Endemic Diseases Control, in the Ministry of Health was established in 1988.

5.4 Application of morbidity control strategy in China

According to the WHO global strategy of morbidity control for schistosomiasis (WHO, 1993), taking into consideration the real situation in China, the national experts put forward the objectives for the control program at three levels: (1) morbidity control, (2) transmission control, (3) transmission interruption. People in different endemic regions can select different objectives based on feasibility and level of economic development. The objectives can be achieved from low level to high level in different stages. For instance, in the marshland regions and mountainous regions, the objectives for the control program are morbidity control, and in some regions with better condition transmission control may be the target of choice, and only in a few regions the target of transmission interruption can be reached. In accordance with the different control objectives, national criteria for control and elimination of schistosomiasis were formulated.

5.4.1 Promotion of morbidity control strategy

The morbidity control strategy was put forward by WHO in 1984. During 1985-1989, field pilot studies undertaking morbidity control were carried out in Hunan, Hubei, and Anhui provinces. During the 'Seventh 5-Year Plan' (1986-1990) and the 'Eighth 5-Year Plan' (1991-1995) of the national control program, investigation projects on optimum strategy were carried out in endemic provinces. The World Bank Loan Project (WBLP) on Schistosomiasis Control started from 1992. In China, morbidity control strategy has been practiced on a large scale in endemic areas during the WBLP period with sustained decrease in prevalence to a low level. The acute schistosomiasis outbreaks became a rarity since then.

5.4.2 Strategies for morbidity control applied in the WBLP for schistosomiasis control in China

Based on schistosomiasis transmission level, the objectives for the WBLP for schistosomiasis control were divided into the following three levels. They were:

(A) reduction of prevalence rate and control of outbreak of acute schistosomiasis;

(B) control of transmission effectively and the prevalence maintaining at a low level;

(C) interruption of transmission of the diseases without new infection.

The WBLP for schistosomiasis control was initiated in 1992. The indexes of the project objectives were as follows: a reduction of human infection rate by 40%, infection rate of cattle and buffaloes by 40%, and infected snail areas, by 50-60%. The project has been carried out in 202 endemic counties in eight provinces, including Hunan, Hubei, Jiangxi, Anhui, Jiangsu, Yunnan, Sichuan and Zhejiang.

The different chemotherapy methods were carried out in different areas based on the endemic situation, which can be divided into three categories: (1) Mass chemotherapy was given in high endemic areas with prevalence rate > 15%; (2) intermittent mass chemotherapy or selective chemotherapy was given in medium endemic areas (prevalence between 3 and 15%); (3) selective chemotherapy was given in low endemic areas (prevalence < 3%).

The numbers of screening and treatment of schistosomiasis during the period of 1995-2000 are shown in Table 6.

Extending chemotherapy was given in high risk regions and persons with a risk of the infection.

Table 6 Schistosomiasis chemotherapy and extended therapy in 1999

	Acute	Chronic	Advanced	Extending chemotherapy (thousand)
Hunan	198	63 311	3942	331.2
Hubei	104	140 987	2413	1082.4
Jiangxi	48	91 502	700	94.7
Anhui	118	1788	16	181.2
Jiangsu	9	1310	69	17.8
Zhejiang	0	0	0	7.1
Guangxi	0	3	0	0
Sichuan	25	2918	219	295.9
Yunnan	11	612	3	74.0
Total	513	302 431	6912	2084.2

In villages where the prevalence was over 20%, people with significant signs or symptoms possibly related to schistosomiasis were given chemotherapy. In endemic areas where prevalence was over 20%, or the people were interviewed, if the person had a history of contact with infested water in the year after last chemotherapy, or the people were accompanied with skin itch, fatigue, abdominal pain or diarrhea, chemotherapy was given. The following data showed that 309.856 thousand cases of schistosomiasis had been treated and 2084.2 thousand persons were provided extending chemotherapy in 1999 without preliminary screening (Table 7).

The data showed that about 2 million people were given extending chemotherapy yearly during WBLP period. About 300 thousand chronic cases of schistosomiasis were treated every year. The number of chronic, acute and advanced cases of schistosomiasis had a big decrease.

5.5 Case study on the morbidity control for schistosomiasis

Although the institutions for schistosomiasis control existed in each endemic county, city, province, the economic situation is constrained in those endemic areas. This problem requires us to carefully analyze local situation and review to assess the feasibility of control with limited resources.

5.5.1 Field background and study sampling selection

The case study was carried out in a marshland area in Guichi County of Anhui Province and shore of the Quipu River whose water runs into the Yangtze River.

Table 7 Numbers of schistosomiasis treatment and screening from 1995 to 2000 in China

Year	Number of screening	Treatment of schistosomiasis	Treatment of acute cases	Treatment of chronic cases	Treatment of advanced cases
1995	10 880 323	339 512	1286	328 733	9493
1996	10 070 290	320 508	1771	309 285	9452
1997	10 176 184	294 372	617	285 154	8601
1998	10 233 435	344 485	1899	335 113	7473
1999	9 487 059	309 856	513	302 431	6912
2000	9 272 674	357 158	664	349 969	6525

The whole study was divided into two stages. The first 4 years was the implementation period (stage one). In this stage the community received the approach of mass chemotherapy. After stopping the intervention, we continued the observation for another 4 years, maintenance period (stage two), to observe the long-term effects of the approach. In the maintenance stage, the mass chemotherapy approach was stopped, elective chemotherapy was given instead. Annual data of prevalence of schistosomiasis and control approaches were collected for 8 years. Those data are used to calculate the results of cost and effectiveness of each alternative. The persons with schistosomiasis asking for treatment were treated by local health workers. In the whole study period, the residents were examined in spring. All other anti-schistosomiasis approaches were given after the examination. In the whole study period, all residents in research communities aged between 3 and 60 years were the subjects for observation. All people were annually examined by Kato-Katz method for *S. japonicum* eggs. The prevalence of schistosomiasis in the three groups was analyzed annually. All people in the study areas were recorded with age, sex, residence and results of examination. The data were red into the computer as the database file for analysis.

5.5.2 The efficacy of chemotherapy

The prevalence of schistosomiasis after chemotherapy is shown in Table 8. Before control, the prevalence of schistosomiasis was 19.23%. During the chemotherapy period, the prevalence was decreasing. When the mass chemotherapy approach stopped, the prevalence increased quite soon. In the sixth and seventh year, mollusciciding was given by local anti-schistosomiasis station. If there were no such approach, the prevalence of schistosomiasis would increase more quickly.

The results of chemotherapy showed that by 1 year selective mass chemotherapy, the prevalence of schistosomiasis reduced from 19.23% to 7.98%. After 4-year chemotherapy, the prevalence reduced to 4.92%. After 4 years implementation, the selective mass chemotherapy stopped, the prevalence of schistosomiasis rose quickly. When chemotherapy stopped for 2 years, the prevalence rose again from 4.92% to 13.58%. The effect on schistosomiasis chemotherapy was evident in just 1 or 2 years in these areas. In this type of endemic area~ schistosomiasis would reemerge yearly. Although chemotherapy can decrease the prevalence in humans, without complemented with snail control, the intensity of transmission is still at a high level. The yearly mass treatment still needs to be recommended in this area.

Table 8 Prevalence of schistosomiasis in the community accepted chemotherapy

Year	Female	Male	Total
Before control	19.18	19.28	19.23
1-	7.93	8.03	7.98
2-	4.25	7.29	5.79
3-	6.21	8.10	7.17
4-	6.25	3.71	4.92
5-	4.69	7.58	6.21
6-	11.79	15.16	13.58
7-	8.73	14.81	11.90
8-	8.48	10.03	9.27

The national data showed us the effect of chemotherapy in schistosomiasis control. During the WBLP period acute, chronic and advanced case of schistosomiasis had decreased almost yearly in China (Table 9).

Chemotherapy has been an important basis of schistosomiasis control. The study demonstrated that appropriate drug treatment lowers worm burden and decreases the intensity of the infection as well as prevalence. Chemotherapy alone can hardly reduce the transmission, because zoonotic *S. japonicum* infection has a great impact on the epidemiology and control of the diseases.

Table 9 Reported cases of schistosomiasis during 1995-2000

Year	Total cases	Acute cases	Chronic cases	Advanced cases
1995	927 314	1286	889 827	36 201
1996	810 502	1771	781 247	27 484
1997	790 851	617	760 526	29 708
1998	762 016	1899	734 264	25 853
1999	756 762	513	731 837	24 412
2000	694 788	664	671 400	22 786

5.6 Maintenance Stage of Morbidity Control

It should be noted that schistosomiasis control is a long-term commitment even though chemotherapy can effectively reduce the prevalence and number of cases. According to the data of 1999, there are 96.3481 million person lived in the endemic areas (Table 10). Areas of snail habitat was 3.466 billion m2. Out of which 94.5% (3.276 billion m2) of the snail habitats were in the marshland areas, 4.450% (154 million m2) in the mountainous and hilly areas and 1.05% (36.5 million m2) in the plain areas.

Table 10 Population in endemic areas of schistosomiasis

Province	Number of endemic county	Population in endemic counties (thousand)	Number of farm in endemic areas	Farm population in endemic areas (thousand)	Population in endemic areas (thousand)
Hunan	29	5415.4	13	334.1	5749.5
Hubei	58	13 547.3	34	396.3	13 943.6
Jiangxi	37	4032.8	19	292.3	4325.1
Anhui	41	5892.4	4	70.1	5962.5
Jiangsu	57	35 762.6	0	0	35 762.6
Zhejiang	54	9470.9	0	0	9470.9
Fujian	14	2467.9	0	0	2467.9
Guangxi	19	743.7	0	0	743.7
Sichuan	62	15 817.6	3	5.4	15 823.0
Yunnan	17	1349.3	0	0	1349.3
Total	338	95 249.9	75	1098.2	96 348.1

The data from schistosomiasis information system showed us that during the WBLP period, the estimated number of infected persons decreased from 927,314 (1995) to 694,788 (1999), the cattle infection rate reduced from 50 to 5.36%. However, a lot of work is needed to maintain a low transmission of schistosomiasis in a long time period. Particularly at present, the end of the World Bank Loan Project on schistosomiasis control in the country will make it difficult in the maintenance stage of the control program. Therefore, attention should be paid to the following aspects.

Table 11 Screening and treatment for cattle and buffaloes in endemic areas

Year	Number of screening	Number of positive	Number of treated	Number of extending chemotherapy
1995	660 486	18 394	16 590	321 611
1996	620 272	48 813	17 612	289 087
1997	626 587	16 224	15 075	340 363
1998	639 073	21 589	20 026	380 337
1999	640 559	22 445	21 626	348 901
2000	616 489	21 270	20 594	283 607

Table 12 The distribution of snail habitats

Province	Snail habitats			
	Total area	Marshland area	Plain area	Mountain area
Hunan	1 748 366	1 700 046	31 019	17 301
Hubei	586 205	576 564	0	9641
Jiangxi	683 154	670 940	0	12 214
Anhui	285 472	263 508	0	21 964
Jiangsu	70 613	64 674	5256	682
Zhejiang	722	0	5	717
Fujian	14	0	0	14
Sichuan	62 733	0	227	62 507
Yunnan	29 186	0	0	29 186
Total	3 466 465	3 275 732	36 507	154 226

5.6.1 Compliance of chemotherapy

The tendency of the decrease in the compliance rate was found with the practice of chemotherapy every year in some places. The best method to improve the compliance was the implementation of health education. After undertaking health education in the Bai national minority in Yunnan province, the compliance rate was improved. The level of knowledge on schistosomiasis significantly increased the coverage rate of chemotherapy in the group receiving health education as compared with the control group. The decrease of human infection rate in experimental group with health education was 52.2% higher than in the control group without the education.

5.6.2 Schistosomiasis transmission still exists in most of the marshland and mountain areas

Effective chemotherapy can reduce human infection rate and intensity of the infection quickly. However, it is difficult to interrupt the transmission. The achievements from chemotherapy are not easy to be consolidated due to the reinfection in residents with a rate between 5% and 47% after chemotherapy according to different authors (Yuan, 1992a,b). Since 1987, synchronous chemotherapy both for humans and bovine had been implemented in Hunan for 10 years. However, human infection rate was fluctuated around 6% since the second year of chemotherapy, i.e. 1988. It was difficult to further decrease the infection rate due to a high reinfection rate. The high-risk persons are the key target population for chemotherapy who need treatment more than once a year.

5.6.3 Bovine as the main infection source of schistosomiasis

In China, 40 mammalian species have been found naturally infected with *S. japonicum* . Cattle, buffaloes and pigs are of great importance in contamination of the marshland. It is quite difficult to treat those animals in the areas. Cattle and buffaloes are major infection source in the marshlands. Mobile cattle population increased recently along with economic development. Cattle are the economic source for the farmers in the region. Although cattle were screened yearly and chemotherapy was given during WBLP period in some areas, the number of infected animals did not have a substantial decrease (Table 11). Cattle as the source of infection are more important than humans in the swamp and lake regions. If we can not control the cattle from schistosome infection, it would be very difficult to control the transmission of schistosomiasis.

5.6.4 The strategy in the maintenance period

It has been noted that the impact of chemotherapy can be maintained for a long time in some places where the snail-infested area is small and people and livestock living in the transmission area are non-migrants. It is clear that large scale chemotherapy can considerably reduce infection rates. Even if encouraging short term results have been obtained, we are still far from satisfactory in long-term solution. If we stop mass chemotherapy for 1 or 2 years, the prevalence would rise again. As long as transmission continues, mass or selective chemotherapy will have to be repeated indefinitely.

Now the approaches we can use for schistosomiasis control in high transmission areas (prevalence above 10%):

- yearly mass chemotherapy to target population;
- snail control by chemical mollusciciding;
- health education;

- safe water supply and sanitation.

In the medium transmission areas (prevalence between 5 and 10%):

- yearly selective mass chemotherapy to target population;
- health education;
- snail control where feasible;
- safe water supply and sanitation.

In the low transmission areas (prevalence less than 5%):

- selective chemotherapy once every 2 or 3 years;
- health education;
- snail elimination;
- safe water supply and sanitation.

5.7 Challenges and Planning in National Control Program in China

At present, we are facing new challenges although great achievements have been made through 50 years' efforts in the national control program. It will be more difficult to maintain the prevalence or morbidity at a low level after mass chemotherapy has been taken for years. More arduous work should be performed to consolidate the achievements gained and to further minimize the transmission areas, to reduce prevalence as well as intensity of infection. Future challenges we are facing are as follows:

1. With the completion of the WBLP on schistosomiasis control in the country by the end of 2000, there are still large areas where schistosomiasis is transmitted (Table 12). The coverage rate and intensity of chemotherapy will decline because of limited resources.
2. After the serious flood in the Yangtze River valley in 1998, both snail-infested areas and the possibility of infection with *S. japonicum* through water contact have been increased. Furthermore, in order to reduce the impact of flood, the China State Council adopted a policy on anti-flooding by 'returning cultured land into the lake and relocation of farmers from endemic areas to newly established towns'. It is one of the new issues in the schistosomiasis control program that

needs investigation, since the policy may contribute to the increase of snail habitats on a large scale, increase of possibility for people in close contact with infested water, and increase of prevalence of schistosomiasis in some areas.

3. The impact of the Three Gorges Dam project on transmission of schistosomiasis in the middle and lower reaches of the Yangtze River is still unclear. There is a need to strengthen the investigation and surveillance on the impact of water levels to the distribution and dispersal of *Oncomelania* snail in the Yangtze River valley.

To overcome the problems we are facing, the following activities are to be implemented in the future:

1. Continuing the activities on strengthening the control program under government leadership, with involvement by relevant departments, and insisting on the policy of taking comprehensive treatment with scientific control approaches.
2. Adjusting the control strategy in time: the control strategy will be adjusted in time after the end of the WBLP. Different endemicity in the endemic areas will be stratified based on the actual situation and changes of prevalence in the country; and different control strategies will be implemented in different endemic areas based on local economic situation as well as on levels of prevalence. The adjusted plan will be studied carefully by experts, and implemented after being critically reviewed by professional staff at different levels. At the same time, the environmental modification will be continued in combination with the construction activities in agriculture and water resources.
3. Strengthening the epidemiological surveillance: It is necessary to strengthening the surveillance in different types of endemic regions. More surveillance pilots will be set up in order to understand the changes of transmission and prevalence in time and provide reliable information for decision making.
4. Strengthening scientific researches: more attention will be paid to the research projects, for instance, the impact of environmental changes on transmission of schistosomiasis. International experts are welcome to get involved in the researches and to cooperate in projects with mutual interests. More international funding for schistosomiasis control and research is, of course, needed.

6 Field Activity Cost Estimates for the First 3 Years of the World Bank Loan Project for Schistosomiasis Control in China

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6.1 Abstract

The World Bank Loan Project for schistosomiasis in China commenced field activities in 1992. In this paper, we describe disease control strategies for levels of different endemicity, and estimate unit costs and total expenditure of screening, treatment (cattle and humans) and snail control for 8 provinces where Schistosoma japonicum infection is endemic. Overall, we estimate that more than 21 million US dollars were spent on field activities during the first three years of the project. Mollusciciding (43% of the total expenditure) and screening (28% of the total) are estimated to have been the most expensive field activities. However, despite the expense of screening, a simple model predicts that selective chemotherapy could have been cheaper than mass chemotherapy in areas where infection prevalence was higher than 15%, which was the threshold for mass chemotherapy intervention. It is concluded that considerable test savings could be made in the future by narrowing the scope of snail control activities, redefining the threshold infection prevalence for mass chemotherapy, defining smaller administrative units, and developing rapid assessment tools.

6.2 Introduction

The strategy of the World Bank Project on Schistosomiasis Control in China was to use mass chemotherapy in high endemic areas and selective chemotherapy in medium and low endemic areas, Snail-control by molluscicide was conducted in areas of high transmission (World Bank, 1989). The strategy was planned by experts from China and abroad in three discussion meetings, on the basis of epidemiological data from a national survey in 1989 (MOPH, 1990a).

During the first three years of the project, data from the evaluation and monitoring indicators on schistosomiasis control in China, as reported annually to the World Bank, indicated a significant reduction in morbidity. The rate of infection and intensity of infection dropped in the eight project provinces, especially in high endemic areas, hut also in medium and low endemic areas. In consequence, the number of areas classified as highly endemic was reduced (Yuan, 1992a,b).

Cost analysis of schistosomiasis control programs is a valuable method of comparing the financial input of different control strategies (Bundy and Guyatt, 1992; Prescott, 1987). In the context of the control program in China, planning for the future requires an understanding of the war the total budget was distributed in the first three years, and how the costs of each strategy compare. In this paper we therefore estimate costs for different field activities of the project, excluding those supported by local government funds. We also compare the potential costs of different strategies in the same communities. The results will serve as a reference for developing sustainable methods of schistosomiasis control in China.

6.3 Methods

Study area

The World Bank Loan Project on schistosomiasis control covered eight provinces including the lake river regions Hunan, Hubei, Jiangxi, Anhui, Jiangsu and Zhejiang, and the mountain regions Yunnan and Sichuan. Hunan, Hubei, Jiangxi and Anhui are the provinces most seriously affected by schistosomiasis. These provinces are located along the Yangtze River and have many lakes, including the Poyang and Dongting lakes, which are the largest lakes in China. Flooding cannot be controlled and snail ridden areas are large. Snail control is difficult. The residents in these areas are at high risk of infection, since agricultural production, fishing and activities of daily living bring them into contact with contaminated water (Wu, 1992). In the two mountainous provinces, despite sparse populations, the level of endemicity is high. In Jiangsu and Zhejiang provinces the infection levels are lower than in the other provinces; however the population is dense and people travel frequently to other areas (Chen, 1989). If these provinces are neglected it would be possible for the disease to break out; therefore they were included in the project. There is a different economic situation in each of the eight provinces.

Strategies of disease control (MOPH, 1990b)

In China, natural villages in close proximity are grouped into units called administrative villages. The administration and operation of the World Bank Project were based on these units. Each administrative village was classified as one of three endemicity groups, defined according to the estimated prevalence of infection. In high endemic areas (prevalence of infection > 15%) mass chemotherapy was applied. In areas of medium endemicity (prevalence of infection form 3-l5%) and low endemicity (prevalence of infection < 3%) selective chemotherapy was applied.

Each year, 30% and 5% of the total population in areas of medium and low endemicity respectively was surveyed. The sampled individuals were drawn from 7-14 year-old children and fishermen as these were groups at highest risk of infection. Individuals positive for S.japonicum infection were treated. All cattle in high endemic areas and Borne cattle in medium and low endemic areas were treated. Mollusciciding with niclosamide was used in some the high transmission areas reduce the snail population.

Mass chemotherapy

In areas of high endemicity, mass chemotherapy was conducted by a mobile team consisting of doctors and specially trained health workers from the county schistosomiasis control station and the township schistosomiasis control group. Team members went to villages where they delivered medication house by house. The teams only left the households after the medication bad been swallowed. A single oral dose of praziquantel was given (40 mg/kg for adults and 60 mg/kg for children).

Selective chemotherapy

Screening was conducted by a mobile team. consisting of technicians and specially trained health workers. Team members went to the village and took blood samples from the high risk groups described above. Blood samples were then tested for the presence of antibodies to *S. japonicum* antigens (using the COP test, the IHA test or the ELISA test). Depending on the local situation, blood samples were tested either in the control station or in the field. All individuals to be positive by antibody detection were treated with a single oral dose of praziquantel (40 mg/kg for adults and 60 mg/kg for children). A second mobile team (including a doctor) was usually responsible for the delivery of medication.

Treatment of cattle

In areas of high endemicity, all cattle were treated by a mobile team consisting of a veterinarian, specially trained staff from the county veterinary station, and individuals from the township veterinary group. Cattle were treated house by house with praziquantel powder (30 mg/kg).

In areas of medium endemicity, treatment of cattle and individuals was conducted simultaneously. The cattle were selected by the local veterinarian, concentrating on those which bad been brought from high endemic areas, and those which often grazed in high- transmission marshland. In low endemic areas the treatment of cattle concentrated on those which bad been brought from high or medium endemic areas.

Snail control

The county schistosomiasis control station organized professional staff to survey snail ridden areas which were near the villages and frequented by many of the residents. If infected snails were found, these areas were treated with niclosamide. The control station gent a technician to organize and guide the local residents in spraying niclosamide at 2 g/m2

Data sources

Data for specific provinces were supplied by provincial schistosomiasis control project offices. These collected data from the schistosomiasis control station in each county and made a report to central government twice a year. The data were related to costs incurred by the provinces, based on their own field activities. For this analysis the following information was supplied by each province: salaries and allowances of doctors, veterinarians and technicians; average distance of each village from the schistosomiasis control stations; average number of individuals treated in one week by one mobile team; average number of square meters treated with niclosamide in three days by one team; average number of cattle treated per week by one team; the unit cost of one antigen detection test. These figures were used to derive province specific unit costs for each activity.

Further data supplied by the provincial offices were related to the overall control effort. These data consisted (for each province) of the total number of individuals and cattle treated, the number of square meters surveyed in snail control activities, and the number of square meters treated with molluscicide for 1992 and 1994. Province-specific figures for 1993 were unavailable. Estimates for each province in 1993 were made by averaging the proportionate contribution of each province in the other two years.

Analysis

Model parameters

For the purpose of this analysis, a standardized model was adopted to describe the mobile control teams involved in the different activities: Treatment of people: 3 doctors and 1 health worker; treatment of cattle: 2 veterinarians and 1 trained assistant; case-identification: 2 technicians and 1 hea1th worker; snail contro1 : 2 technicians and 10 10cal residents.

Unit costs

For each activity (treatment, screening and snai1 control), unit costs were calcu1ated under the headings of personnel, vehic1e, and consumables, following the convention of Guyatt et al (1994). Parameters were taken from data supplied by the provincia1 schistosome control offices. Denominators were re1ated to the activity; thus unit costs for screening and treatment activities were ca1culated per person, or per head of cattle. For snail surveys and control, the denominator was the number of 10,000 m2 surveyed or treated respectively. For the purposes of this analysis, all costs are reported in US dollars (I US $ = 8.5 RMB Chinese Yuan).

Total expenditures

Total expenditures were calculated by multiplying the appropriate unit costs by the total number of treatments (human and cattle), or by the area treated with molluscicide. The total costs of each activity under the headings described above were calculated, in addition to the total costs of each activity in each province.

Comparative costs of different strategies

A comparison was made between potential cost of a selective chemotherapy strategy, in which all individuals are screened and only infected individuals are treated, and a mass chemotherapy strategy, in which all individuals are treated. It was assumed that the time spent on the two strategies would be equal, and that compliance would be 100%. The specificity of the test was assumed to be 100%. The cost of each strategy was calculated for areas with infection prevalence between 0 and 100%. For this analysis, the size of the population was not required; thus the outcome is applicable to large or small populations. Several comparisons were made, using the unit costs as calculated above for each province. This approach enabled the expected costs of different strategies to be compared within each province, at different levels of infection.

6.4 Results

We estimate that over 7.5 million people were treated in the first three years of the control project; 53% in high endemic areas and 47% in medium and low endemic areas. Mass chemotherapy in high endemic areas covered almost 11,400 villages and treated 4.3 million individuals at an estimated cost of US$ 1.7 million. Selective chemotherapy covered approximately 133 thousand villages where endemicity was medium or low. The screening of 15.9 million individuals in these villages cost approximately US$ 4.9 million, and the subsequent treatment of 3.4 million individuals cost an estimated US$ 1.5 million. The total cost of cattle treatment is estimated to be US$ 1.5 million. Molluscicide application over 850 million cost approximately US$ 10.5 million, and surveys for sites with infected snails are estimated to have cost an additional US$ 1.1 million. The total cost of the disease control activity is therefore estimated to have been more than US$ 21 million over the first three years.

Table 13 shows the estimated total expenditure for each activity, divided into costs for personnel, transport and consumables. The table also shows the proportionate cost of each item as proportion of total operational expenditure. Screening accounted for the greatest proportion of personnel costs, which accounted for almost half the total expenditure. Of the consumable costs, mollusciciding accounted for the greatest amount, and is estimated to have been the single most expensive activity during the first three years of the project.

Table 13 Costs and expenditures (US$ 1994)

The estimated cost (US$ 1994), and percentage contribution to the total expenditure, of different activities within the schistosomiasis control program, under the headings of personnel, vehicle and consumable costs.

	Personnel	(%)	Vehicle	(%)	Consumable	(%)	Total	(%)
Treatment of humans	2,694,347	10%	230,944	1%	1,770,571	7%	4,695,862	18%
Treatment of cattle	708,319	3%	66,823	0%	1,082,526	4%	1,857,668	7%
Screening	5,884,989	22%	477,161	2%	1,113,376	4%	7,475,526	28%
Survey	1,079,577	4%	0	0%	0	0%	1,079,577	4%
Mollusciciding	2,145,592	8%	264,583	1%	9,017,950	34%	11,428,125	45%
Total	12,512,824	47%	1,039,511	4%	12,984,423	49%	26,536,758	100%

Table 14 shows the total amount spent on field activities in each province, over the first 3 years of the project. There was wide heterogeneity in the total expenditure by province, ranging from US$ 0.6 million (Zhejiang), to US$ 7.9 million (Hunan). In Hunan, Hubei, Jiangxi, and Anhui, mollusciciding was the most expensive activity. In Jiangsu, Zhejinag and Sichuan, the most expensive activity was screening. In Yunnan, treatment of humans and costs of screening were approximately equal. Fig. 14 shows the distribution of total expenditure by province. The differences reflect the different levels of endemicity in the various provinces, leading to different control strategies, and also differences in unit costs.

Table 14 Total estimated costs

The total estimated cost (US$ 1994) of different activities in each province, during the period 1992-1994.

	Hunan	Hubei	Jiangxi	Anhui	Jiangsu	Zhejinag	Yunnan	Sichuan	Total
Treatment of humans	1,103,471	851,996	357,522	215,130	39,430	33,916	153,437	489,577	3,244,479
Treatment of cattle	717,906	317,469	154,378	78,954	4,574	12,313	81,954	122,873	1,490,421
Screening	996,261	961,896	496,201	242,293	1,085,024	466,559	136,120	509,040	4,893,394
Survey	340,020	346,944	143,628	58,224	124,031	57,256	18,066	12,880	1,101,049
Mollusciciding	4,807,005	2,986,159	965,750	640,842	851,740	3,770	104,904	106,304	10,466,474
Total	7,964,663	5,464,464	2,117,479	1,235,443	2,104,799	573,814	494,481	1,240,674	21,195,817

Comparison of unit costs by province

Table 15 lists the unit cast of each field activity by province. Unit costs are presented for consumables, personnel and vehicles. As a result of differences between provinces in terms of geography, population density, distances from control stations to villages, and accessibility of villages and snail habitats, the average number of treatments and amount of snail control activity per unit time also varied. Variation in data supplied by the provincial offices also reflected the use of different strategies in different provinces, depending on the level of endemicity.

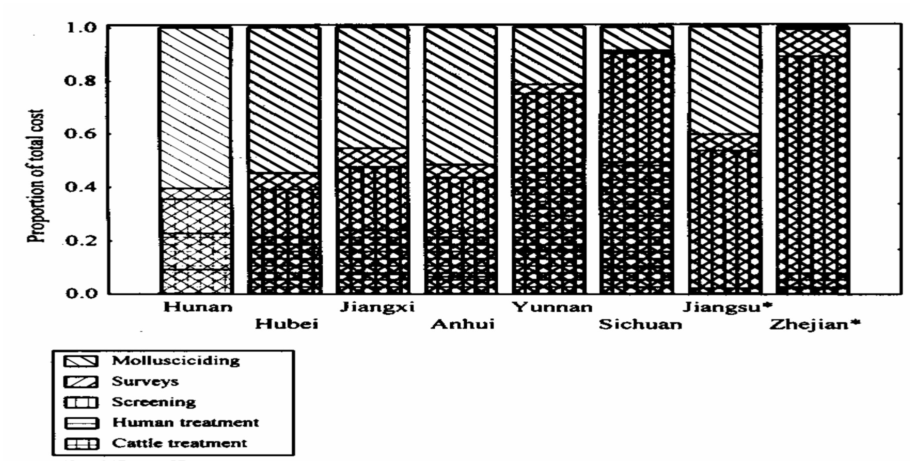

Figure 14 The percentage contribution of the cost of each component activity to the overall field activity expenditure within each province, during the three years period 1992-1994. All figures in US$

Consumables

For consumables, the unit costs for medication and niclosamide were the same throughout, as they were purchased in bulk by the Ministry of Public Health. A tablet of praziquantel cost US$ 0.23 per person, and praziquantel powder cost US$ 1.62 per head of cattle. Niclosamide cost US$ 106 per 10 thousand square meters. The costs of the consumables used in screening tests varied as they came from different suppliers.

Personnel

The unit costs for personnel varied considerably from province to province for the same activity. This was partly because salaries and local conditions varied, and partly because of geographical differences. Traveling time, for example, was much longer in the more mountainous provinces.

Table 15 Unit costs of field activities (US$ 1994)

Unit costs of each field activity (US$ 1994) by province. Average costs are given in the final columm.

	Hunan	Hubei	Jiangxi	Anhui	Jiangsu	Zhejinag	Yunnan	Sichuan	Average
Treatment of humans									
Personnel	0.17	0.09	0.21	0.18	0.7	0.93	0.26	0.29	0.35
Vehicle	0.02	0.01	0.02	0.02	0.04	0.06	0.02	0.02	0.03
Medication	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Total	0.42	0.33	0.46	0.43	0.97	1.22	0.51	0.54	0.61
Treatment of cattle									
Personnel	0.6	0.31	0.2	0.88	1.84	2.06	0.71	0.99	0.95
Vehicle	0.09	0.06	0.03	0.11	0.13	0.18	0.08	0.11	0.1
Medication	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62
Total	2.31	1.99	1.85	2.61	3.59	3.86	2.41	2.72	2.67
Screening									
Personnel	0.25	0.14	0.28	0.14	0.44	0.38	0.23	0.15	0.25
Vehicle	0.04	0.03	0.04	0.02	0.04	0.04	0.03	0.02	0.03
Reagents	0.06	0.02	0.05	0.05	0.08	0.05	0.08	0.05	0.06
Total	0.35	0.19	0.37	0.21	0.56	0.47	0.34	0.22	0.34
Mollucididing									
Personnel	10.9	12.7	16.3	18.3	39.8	31.2	40.3	32.6	25.26
Vehicle	1.92	1.97	2.34	2.25	1.88	3.46	4.8	6	3.08
Niclosamide	106	106	106	106	106	106	106	106	106
Total	118.82	120.67	124.64	126.55	147.68	140.66	151.1	144.6	134.34
Snail survery	4.71	4.92	3.76	3.52	3.45	3.52	4.9	5	4.22

The highest unit costs for personnel were in Zhejiang (US$ 0.93) and Jiangsu (US$ 0.7). The large discrepancy with respect to other provinces was due to higher salaries and allowances. Unit costs were also relatively high in Yunnan and Sichuan Provinces. In these provinces salaries and allowances are not very different from those in the remaining provinces, but the villages are a long war away from the schistosomiasis control station. The average distance is 80 km, which is 30 km further than in the other provinces.

Screening

Costs varied due to differences in personnel costs, mainly because each province had its own method for screening. Costs also depended on the price of the reagents and the time required, which were not necessarily the same in each province, since there was no central supplier. Hunan, Hubei, Jiangxi, Anhui, and Yunnan Provinces used an Indirect hemagglutination test, Jiangsu Province used the circumovum precipitate test, and both Zhejiang and Sichuan Provinces used ELISA based technics.

Treatment of cattle

The cost of this activity in the whole project accounted for only 7% of the total expenditure. However, the unit cost for the treatment of cattle was four times higher than that for humans. The main reasons are that praziquantel powder is more expensive than tab lets, and the treatment of cattle is more time-consuming than the treatment of humans. Also, farmers often need considerable persuasion before they allow a procedure that they perceived as potentially debilitating for the animals, and this results in a low number of treatments per unit time.

Snail control

As with the treatment of humans, the unit costs varied although the cost of consumables was fixed. Unit costs in Jiangsu and Zhejiang Provinces were high, as salaries and allowances are higher than in other provinces. However, in Yunnan and Sichuan Provinces the manpower expenditure was about double that in the remaining four provinces. Yunnan and Sichuan Provinces are in mountainous regions, where the geography and the environment are complicating factors. The areas surveyed were not large, but more of them were snail-ridden. As a result of these factors, snail control was not easy to carry out, and required more time and manpower than in other provinces.

Comparison of different strategies

Having calculated the unit costs of treatment and screening, it was possible to calculate the expected costs of two different strategies in each province. The cost per person for the mass chemotherapy option was assumed to remain constant in one province, and vary between provinces according to heterogeneities in personnel costs. The cost of the selective chemotherapy option included the costs of screening, which varied considerably between provinces, due to the different methods of screening, and different levels of endemicity within each province.

Fig. 15 shows the ratio of the expected costs of mass chemotherapy and selective chemotherapy strategies in each province. Where the ratio is equal to one, the costs of two different strategies are equal, and when it falls below one, selective chemotherapy is estimated to be cheaper. As the unit costs vary between provinces, there is a marked difference between provinces in the prevalence of infection where the two strategies are equally expensive. The figure show that when the prevalence is below 20%, it would be cheaper to use selective chemotherapy in all the provinces, except in Jiangxi and Hunan, where the costs of two strategies would be approximately equal. However, the model predicts that in same provinces selective chemotherapy would still be cheaper at considerably higher prevalence levels. At 50% infection prevalence, selective chemotherapy would still be cheaper than mass chemotherapy in Anhui, Zhejiang and Sichuan Provinces.

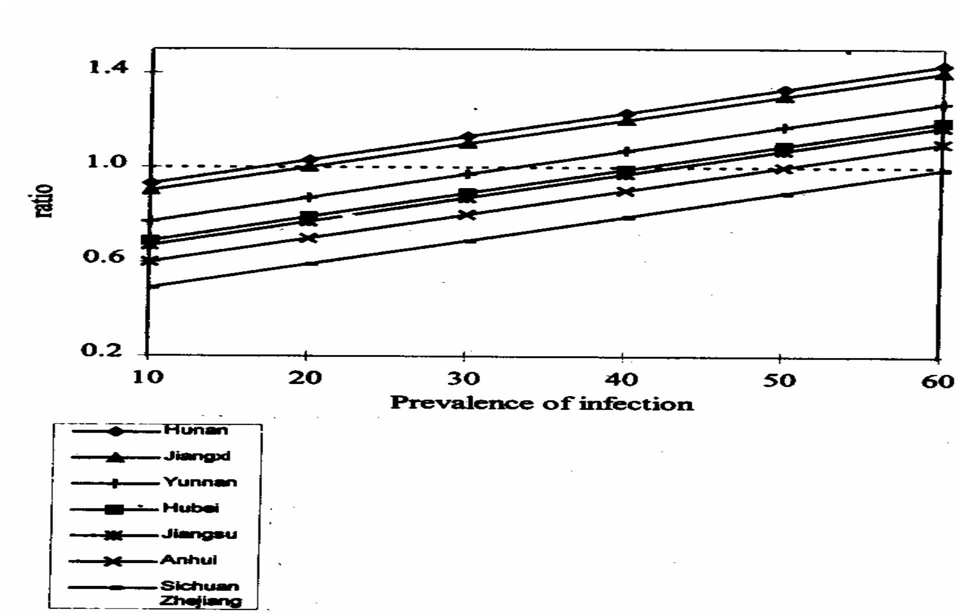

Figure 15 The expected cast of a mass chemotherapy strategy compared with the cast of a selective chemotherapy strategy, for different infection prevalence in each province. Each line represents the cast ratio of the two strategies (selective/mass). The dotted line represents cast equality; ratios above this line indicate that mass chemotherapy would be the cheapest option. Ratios for Sichuan and Zhejang provinces are represented by one line, as the estimates for these provinces were equal to one decimal place.

6.5 Discussion

In the analysis presented here, we used data provided by provincial field stations to estimate unit costs for the main components of field activities. From the available data, we also estimated that more than US$ 21 million was spent in the first three years of the project. This is unlikely to be a precise estimate, since we adopted a standard model to calculate unit costs. In particular, data supplied by provincial offices related to experiences using their own control teams, with potentially different personnel than used in the model. In addition, assumptions regarding the time spent on each activity in different areas may alter the relative cost of each activity in different provinces. Nonetheless, we can draw inferences from the results which may be useful in the long term control of schistosomiasis in China, particularly in the development of cost effective strategies.

In the first phase of the project, mass chemotherapy was used in all areas of high-endemicity, defined as those with a rate of infection over 15% (on the basis of older medical records). Mass chemotherapy had played an important role in large-scale schistosomiasis control pro grams, hut it inevitably involves wastage if a large number of uninfected people are treated. The preliminary results presented here indicate that selective chemotherapy is cheaper than mass chemotherapy in areas with a prevalence of *S. japonicum* infection higher than 15% - in almost all provinces the cost of a strategy based on selective chemotherapy is estimated to be lower at 20% infection prevalence, and in some provinces selective chemotherapy may be cheaper at 50% infection prevalence. Results from surveys suggest that the distribution of *S. japonicum* infection is highly focal, and only in rare patches does it reach 40% or higher (Yuan, 1992a,b).

The analysis did not account for variations in the specificity of the tests or compliance rates. Low values for either of these parameters would reduce the number of infected individuals treated if selective chemotherapy were to be used. The costs of the two strategies would not be affected, hut a mass chemotherapy strategy would be more effective in this situation heterogeneities in the costs of different items, which may alter the attractiveness of a strategy in a particular location, were also not considered. Whereas a reduction in screening costs would reduce the cast of a selective chemotherapy strategy, a reduction in the price of medication would have the greatest effect on the cast of a mass chemotherapy strategy.

During the control project, classification into endemic levels was based on the unit of the administrative village. An administrative village covers a large area and consists of many settlements (in same cases more than 20 villages), which may differ from each other in geographical features, occupations, professions and behavioral habits of the inhabitants. All these factors can influence the prevalence of infection. Therefore it may be more effective to consider the endemicity level of individual settlements rather than administrative villages when deciding whether to use selective or mass chemotherapy. This would involve more screening; however, the results of the present analysis suggest that the extra cast may be outweighed by the saving on medication if only infected individuals are treated. This approach may be more readily accepted by the community if fewer uninfected residents are treated.

Calculations presented here demonstrate that snail-control was a particularly expensive activity. The approach used in China, namely the identification of areas with infected snails be fore application of niclosamide, ensured that mollusciciding was focal. This approach has been demonstrated to be more cast effective than area-wide snail control (Klump and Chu, 1987). Nonetheless, snail control still accounted for the largest percentage of the budget in medium and high endemic areas. The biggest item in the cast of snail control was the niclosamide treatment of one million m2 of snail habitat was equal to the cast of medication for 23,000 patients. Further, the specific benefits of mollusciciding could not be estimated, and therefore it is not clear to what extent snail control contributed to the reduction in infection prevalence. This clearly indicates the need for well defined outcomes to be introduced into future study design.

The results of the present analysis suggest three possibilities for reducing expenditure in the future. First, classification of endemicity by natural village rather than administrative village could lead to more precise targeting of intervention, thus reducing drug costs. Related to this is the possibility of using selective mass chemotherapy (Prescott, 1987) in groups at highest risk of infection. Second, in areas of low and medium endemicity, more economical methods for screening before treatment could be developed. Although low-cost, rapid-assessment, techniques have so far only been developed and validated for *S. haematobium* (Lengeler et al, 1991; Red Urine Study Group, 1995) and *S. mansoni* (Odermatt, 1994, Utzinger et al., 2000), a questionnaire based approach also be feasible for *S. japonicum* infections (Booth et al, 1996). Third, the scope of snail control could be narrowed down as much as possible; concentrating on areas where there is greatest contact between infected snails and humans.

After the first three years of the schistosomiasis control project in China, many areas were classified as low- or medium-endemic. One challenge for the future will be to maintain a 10w prevalence of infection. The results of this analysis are presented in such a war that they can easily be incorporated into frameworks used by program managers who wish to evaluate various control options at different levels of endemicity. However, it should be noted that the unit costs are applicable only to vertical program, which may be unsustainable when there are severe budget limitations (Evans, 1992). The future of the schistosomiasis control program in China may therefore have to be considered in the context of inclusion into other health care strategies. In addition, it will be important the contribution of individual activities to reduction in infection and morbidity, in order to develop the most cost-effective strategies. This may require alternative diagnostic procedures, involving collection of parasitological and morbidity data in parallel with control activities.

7 The 1992-1999 World Bank Schistosomiasis Research Initiative in China: outcome and perspectives

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7.1 Abstract

Ongoing efforts over the last 50 years, aiming at the elimination of schistosomiasis in the People's Republic of China, have been spectacularly successful in reducing the prevalence and intensity of the infection. The endemic areas have been reduced to core regions with particular problems such as the middle and lower reaches of the Changjiang River (Yangtze), the land adjacent to the lakes of central China and certain mountainous areas in Sichuan and Yunnan. An effort to eradicate schistosomiasis as a public health problem in these areas, by means of mass chemotherapy in regions of high prevalence and selective chemotherapy in others, provided good results initially but a lasting effect proved unattainable with chemotherapy alone. A small part of the funds available for this effort were used for research and training. Overseen by a Joint Research Management Committee (JRMC), research training was intensified resulting in improved applications and a better quality of the scientific level of the research finally carried out. Several new control tools were produced which may improve future control approaches, which might achieve a more than temporary relief. In evaluating the contributions made, it was found that the great environmental variations between the eight provinces where control activities were implemented was the main reason why general use of chemotherapy only could not be entirely successful. The inclusion of a research component proved beneficial both for the short- and long-term control and the JRMC proved useful in exposing that sustained progress cannot be achieved without back-up by other approaches, e.g. snail control. Suggested future activities include strengthening of intersectional and industrial collaboration but finding financial support for continuing the JRMC initiative in some form. It is crucial to consolidate progress made.

Key words: Schistosomiasis; Chemotherapy; China; Control; Diagnosis; Epidemiology; Research

7.2 Introduction

The impact of schistosomiasis around the time the PR of China was created was of such extent that the question was immediately brought to the highest level of authority. A government-led control program was initiated and operated at full force between 1955 and 1986 when its responsibilities were taken over by the Office for Endemic Diseases Control under the Ministry of Health. Estimates of the number of people infected when the first nation-wide control project was carried out in the 1950s range from 5 million to almost 12 million with more than 100 million people at risk (Mao and Shao, 1982; Basch, 1986; Mao, 1990). Using available methods with a strong emphasis on environmental management, interruption of transmission in four of 12 provinces was achieved early on but the objectives could not be reached everywhere (Chen, 1999; Yuan, 1995). The progress over the last few decades has still been impressive (Figures 16 & 17). However, it should be noted that substantial endemic areas in regions dominated by swamps, lakes, hills or mountains remain since the control activities there are much more difficult to be sustained than elsewhere. It was against this background, that a renewed effort to finally eliminate schistosomiasis as a public health problem was mounted by initiating a 5-year control project in collaboration with the World Bank in 1992. This undertaking was negotiated within the framework of a program to control tuberculosis and schistosomiasis, the current two major health problems in China. The schistosomiasis component, supported with USS 82 million from the government of the PR of China supplemented with an International Development Association (IDA) loan of USS 71 million, was later extended for 3 more years until 1998. The project was implemented by the Bureau of Disease Control (formerly the Office of Endemic Diseases Control) of the Ministry of Health (MOH) in collaboration with the health departments in each of the eight affected provinces. The stated objective was to reduce the prevalence in the endemic areas, not only in the human population but also in cattle and buffalo, with 40%, and to decrease the density of infected snails by at least 50%. The approach chosen was to attempt controlling morbidity using mass chemotherapy in highly endemic regions and selective chemotherapy in areas of medium and low endemicity coupled with limited snail control through mollusciciding and environmental modification.

Operational research is considered important by the World Bank and during the negotiations for the schistosomiasis component of the IDA loan, assurances were obtained that a Joint Research Management Committee (JRMC) be established for this purpose in collaboration with the MOH and the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR).

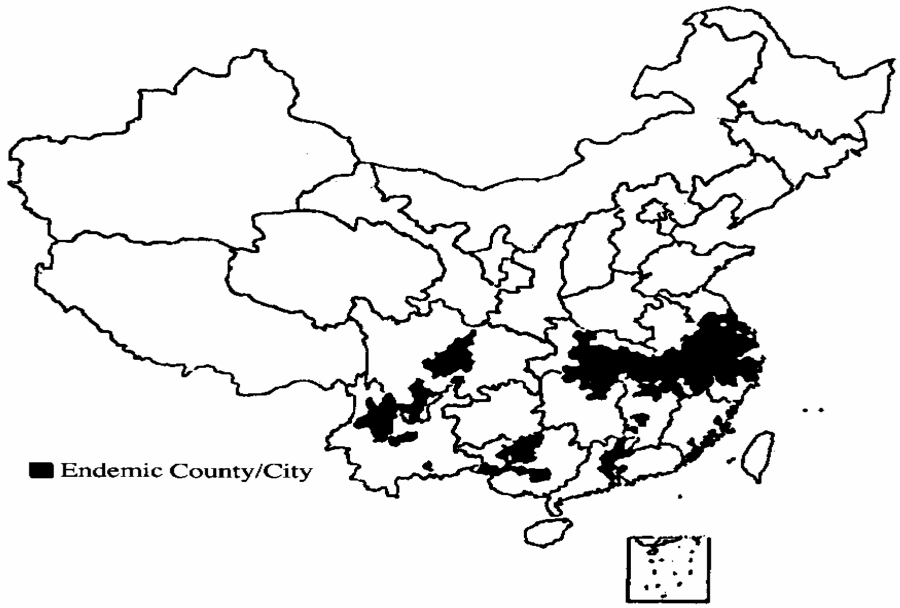

Figure 16 Regional distribution of *Schistosoma japonicum* infection before control

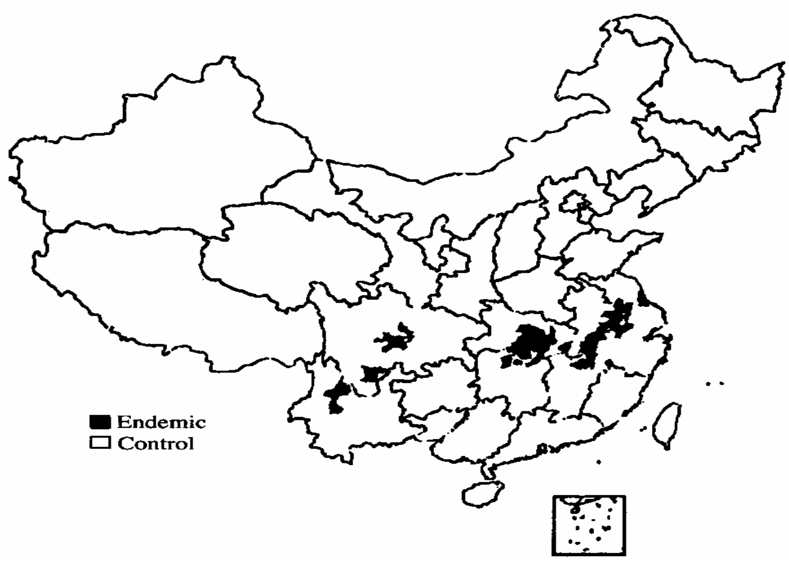

Figure 17 Regional distribution of *Schistosoma japonicum* infection after control

This collaboration was co-funded with USS 2.94 million from the IDA loan and USS 1.36 million from the provincial governments and it was maintained during its 7 years of project implementation. JRMC provided guidance and distributed funds supporting specific research projects within its area of expertise stimulating young researchers in each of the endemic provinces. International communication and research collaboration were strengthened and a large number of scientists received training through dedicated workshops. The overall impact on endemicity and, particularly, on the intensity of disease due to schistosomiasis during the period has been favorable, e.g. Zhejiang Province was declared eradicated in 1996 and in others the number of villages, classified as sites of high, medium or low endemicity, was reduced by 20-50% (OEDC, 1997a). However, in spite of the good progress, a further reduction of the prevalence in the world, aimed at creating an artificial lake west of the Three Gorges of the Changjiang (Yangtze) river in the Sichuan, and the recent scheme to return land claimed from the lakes by dikes in an effort to reduce the risk for future inundations, may lead to increased transmission if countermeasures are not properly implemented. The situation must therefore be carefully monitored and a strategic reorientation may be required.

7.3 Research objectives

The tools for controlling schistosomiasis in China are traditionally based on chemotherapy and snail control using environmental modification. The JRMC strategy was to add new approaches by encouraging research to improve morbidity control, ensuring its cost-effective application in the field for the long term, and to help raise the quality of management at all levels. The areas of health education, social and economic research were particularly emphasized and studies were funded with the objective to improve monitoring, surveillance, evaluation and economy, paying special attention to diagnostic tests suitable for detecting resurgence of transmission. In addition, support was given for the standardization of the use of ultrasound and its application to emergence/reversal of morbidity and the study of the relationship between prevalence and intensity of infection. There was also an interest in promoting research on symptoms in different settings, clinical management of patients with acute and advanced disease as well as sanitation, water management and cost-effective methods of molluscicide application.

In 1995, in the light of emerging results from a second national survey, the original objectives were re-evaluated and it was decided to direct support towards the consolidation of achieved progress. To that end, activities were concentrated on surveillance and treatment with a strong focus on diagnostic techniques, development of strategies for efficient snail surveys including development of new molluscicides and the development of cost-effective control management in the different endemic areas. Further, validation of the impact of health information, education and communication (IEC) was moved to center stage together with the integration of this concept into control strategies based on the assessment of oral drugs for the prevention and early treatment of various risk groups, e.g. assessment of simple and effective methods to prevent and treat upper gastro-intestinal bleeding due to liver fibrosis in advanced schistosomiasis.

7.4 Management

The control project was administered by the Office of Endemic Diseases Control (OEDC) and the Director, OEDC was directly in charge of operational research. In this he was supported by the JRMC consisting of seven Chinese members, two TDR staff and two international experts coopted through TDR. Although JRMC recommended projects for approval and decided over fund allocation, the actual release of the funds was the responsibility of the MOH Foreign Loan Office. Supervision of the control project was carried out by the World Bank through a team including one JRMC member. These visits were organized by OEDC and carried out biannually, and included an overview of the JRMC operational research activities. Annual reports discussed both research and control issues and were based on project meetings convened twice a year. In addition, the Director, OEDC kept the State Council, the highest level of executive government in China, a jour by periodic presentations of schistosomiasis policy and progress.

Standardized forms were used and research proposals were invited, both in Chinese and English, to the provincial offices biannually by 31st January and 31st July, respectively. After a first screening for quality, conducted by schistosomiasis expert advisory committees in the provinces (except for proposals from institutes affiliated with MOH), the Chinese JRMC members carried out a preliminary review. Proposals, which passed this review, were evaluated in depth and submitted to plenary discussion. If an unanimous opinion could not be reached, a vote was taken and only applications with more positive than negative votes were approved. In this way, applications were either approved as proposed, approved with revisions or rejected. Some applicants with interesting proposals, which could for various reasons not be approved directly, were given appropriate advice and invited to resubmit. Most proposals were approved after various degrees of revision. Activities carried out by the Chinese JRMC members between meetings included supervision of all operational research and on-site evaluation of ongoing projects. Investigators were required to submit annual reports which, depending on the topic, were allotted to a specialist member from JRMC for review. Although the operational research was carried out in the provinces, it needed to be centrally directed and monitored to avoid duplication and mistakes and to ensure a sound policy analysis. In addition, it was decided that the questions to be examined should have a broad scope and be of significance for the program as a whole. A forum for the exchange of ideas and dissemination of findings among researchers and provinces was also deemed a necessity.

Table 16 Funds by province

Distribution of funds (in RMB) by province[a]

Province	Approved	Disbursed	Proportion (%)
Hunan	3 132 254	1 668 400	53.3
Hubei	3 002 140	2 312 790	77.0
Jiangxi	3 681 530	2 580 130	70.1
Anhui	2 376 185	2 376 185	100.0
Jiangsu	1 601 638	1 120 245	69.9
Sichuan	2 103 180	1 200 618	57.1
Yunnan	1 171 875	1 117 625	95.4
Zhejiang	1 354 298	960 548	70.9
Central unit	2 613 000	2 483 000	95.0
Total	21 039 100	15 822 541	75.2

[a] Distribution of funds over the period of the programme (up to April 1999).

Serious difficulties related to fund distribution were experienced owing to the inability of some province governments to comply with the World Bank policy of advancing approved funds to be subsequently reimbursed against receipt. This led to long delays in the execution of many projects and, in some cases, approved priority projects had to be abandoned altogether. Another difficulty was that once funds had been awarded, JRMC had no mechanisms for exerting control. Consequently, a project could not be canceled if not carried out in terms of the original design or the second-year payment suspended if the work did not progress well. By JRMC-7, in

1995, the system was reformed making it possible for the Central Ministry of Finance to advance part of the funds, a policy made retrospective so previously delayed payments could be transferred. MOH and the provincial project offices made every effort to assure an uninterrupted cash flow and worked with other government sections to accomplish this. As a result, 100% of the funds was released in Anhui and Yunnan and the central component released 95.4% and 95.02%, respectively. The Hubei, Jiangxi, Zhejiang, Jiangsu Sichuan and Hunan provincial governments released from 53.27 to 77.04%. Table 16 highlights the financial situation by the end of the programme (up to April 1999), and clearly shows that the ratio between funds approved for local investigators and actual access varied greatly between the provinces and that 1/4 of the total available funds was in fact never used.

7.5 Research activities

The total amount disbursed over the period (1992-1997) was RMB 21,039,100 corresponding to USS 2,541,629. Out of more than 913 proposals submitted, as many as 245 (27%) were recommended for funding. Table 17 indicates how many proposals were received in each area of research and the proportion approved, while Table 18 summarizes the distribution of funds according to research area, academic level and province. As can be seen, health economy and control strategies were the two most popular subjects among the investigators but the quality of proposals was superior in the fields of chemotherapy and snail control. Even if the number of proposals focused on chemotherapy was less than 3%, (Table 17) and the proportion of approved projects did not make up more than 6.5% overall (Table 18), their generally good quality of design and feasibility in combination with the high potential for short-term impact contributed to a proportionally much higher rate of approval (Table 17). In fact, the development of novel approaches to chemotherapy turned out to be the field where the most important discoveries were made and some of these projects were among the most innovative reviewed. It is further evident from Table 18 that most studies originated at the provincial level and that control strategies, snail control and immunodiagnosis were the most well-funded fields of research.

In addition to the JRMC review, all approved proposals were also examined thoroughly by the MOH. As of April 1999:

- 137 projects have been completed;
- 83 projects are still ongoing;
- 22 projects could not be finalized before project funding was terminated;
- 35 of 41 projects were considered to have been completed with excellence and awards were recommended for the investigators; and
- Well-developed projects concerning priority
- subjects (Table 19) were presented in detail by the investigators at the JRMC final conference in Wuhan, China.

Table 17 Approval rates

Approval rates in relation to research area[a]

	Submitted	Approved	Rate (%)
General control strategies	231	80	34.6
Chemotherapy	24	16	66.7
Immunodiagnosis	140	57	40.7
Snail control	100	50	50.0
Health economy	270	25	9.0
Health education	60	17	28.3
Total	913	245	26.8

[a] Popularity of subjects compared to actual funding.

The progress of operational research was generally satisfactory in solving existing problems of techniques and management. However, further obstacles were discovered by JRMC during the process of project implementation, which led to a re-evaluation of some specific objectives in 1995 and an adjustment of the priorities. For example, proposals on the prophylactic use of artemether and artesunate, investigation of the impact of environment modification and the need for new strategies in the consolidation period, were put forward only after that time. Most notable achievements are the advances in immunodiagnosis, including the establishment of a National Reference Centre with provincial serum banks, preventive treatment with artemisinin derivatives, improved methods for the surveillance of cercariae-infected water, cost-benefit analyses comparing various strategies, and the national schistosomiasis surveys.

Table 18 Funds distribution

Distribution of funded projects[a]

	Number	Proportion (%)
By research area		
General control strategies	80	32.7
Chemotherapy	16	6.5
Immunodiagnosis	57	23.3
Snail control	50	20.4
Health economy	25	10.2
Health education	17	6.9
By institutional level		
MOH-affiliated institutes and universities	34	13.9
Provincial institutes and schistosomiasis stations	186	75.9
Prefecture-level institutions and stations	15	6.1
County-level institutions	10	4.1
By province		
Anhui	29	11.8
Hunan	37	15.1
Hubei	36	14.7
Jiangxi	44	18.0
Jiangsu	21	8.6
Sichuan	25	10.2
Yunnan	12	4.9
Zhejiang	17	6.9
Central unit (MOH)	24	9.8

[a] Distribution of the 245 funded projects according to research area, academic level and province.

In 1995, the second nationwide survey on the situation of prevalence of schistosomiasis at the national level (funded at 2,731,928 RMB by JRMC) took place. Through comparing the results with that of the previous survey of 1989 the effect of schistosomiasis control could be assessed. A comparison of data from these nationwide surveys indicated a prevalence reduction between 1989 and 1995 of close to 50% in human, and a 32% reduction in the prevalence of infection in livestock such as cattle and buffalo. The surveys have assisted in the evaluation and modification of the schistosomiasis control program by providing methodologically improved quality and more valid and precise data. However, it is clear that a third survey is needed to confirm the improvements. In fact, one of the important lessons learnt is that it would be useful to establish a surveillance system that could not only validate interventions made, but also be a reliable data source regarding the development of prevalence and incidence in the country over longer periods of time.

Table 19 Strong impact projects on control strategies

Projects with a strong impact potential on control strategies[a]
The use of artemether and artesunate in prevention of schistosome infection
Implementation of a new technique for the control of snail infiltration in river irrigation systems
Application and evaluation of school-based health education emphasizing the risk for schistosomiasis
Cost-effectiveness of inquiry-based targeted chemotherapy compared to mass chemotherapy in heavily endemic areas
Techniques for the rapid evaluation of schistosomiasis prevalence in lake and marshland regions
Development, application and evaluation of a rapid diagnostic kit for the detection of a *Schistosome japonicum* circulating antigen

[a]A selection of particularly well-managed projects for which the investigators were awarded special honours.

The JRMC activities during the 7 years included some techniques and approaches showing promise for future integration in control activities and some that could be implemented directly. A total of 278 of these were published: 52 from Hunan, 44 from Hubei, 27 from Jiangxi, 21 from Anhui, 31 from Jiangsu, 40 from Zhejiang, 35from Sichuan, 11 from Yunnan and 17 from the central component. Twenty-five projects won prizes above the province level and seven projects obtained patents. Some results included novel techniques and approaches, which have already been implemented in the field, e.g.:

- Xiao Shuhua and colleagues at the Shanghai Institute of Parasitic Diseases showed that artemether, when given weekly as prophylaxis against infestation of cercariae, showed very promising results (Xiao et al, 1995; Xiao et al, 1996a,b). At the same time, Li Shiwen and coworkers at the Zhejiang Institute of Parasitic Diseases found a similar result with another artemisinin derivative, artesunate (Li et al, 1996). Li's research group further demonstrated during the flooding of the Yangtze river in 1998 that artesunate was a safe, highly efficient preventive drug which was able to protect from infection the great majority of the more than 90,000 soldiers fighting the floods (Li et al, 1996). Both artemether and artesunate showed a significant schistosomulocidal effect in experimental studies and field trials, closing the 5-21-day gap when praziquantel is relatively ineffective. This novel application of artemisinin derivatives, which are otherwise used against malaria, is probably the most important discovery in the field of schistosomiasis in recent years. The therapy prevented maturation of *S. japonicum* infections in pilot studies carried out in

Jiangxi, Yunnan, Hunan, Hubei and Anhui provinces (Li et al, 1996; Song et al, 1998; Wang et al,1997; Xu et al, 1997; Xiao et al, 1996a,b).

- A study on the method of rapid evaluation of prevalence of schistosomiasis in marshlands and lake regions by Zhao Gengmin et al. of Shanghai Medical University showed that Lot Quality Assurance Sampling (LQAS) can be used to evaluate the infection level, especially in highly endemic areas (Zhao et al, 1999). This approach proved a good method to evaluate the prevalence level and to provide the scientific basis for formulating and adjusting current control strategies.
- A new cercariometry method, based on a plastic which absorbs cercariae electrostatically was developed by Cai Shichun et al. at the Nanjing Medical University (Cai et al, 1993). This technique is rapid, sensitive and simple, yet superior to older methods based on absorption to nylon-tissue, water filtration or the use of sentinel mice. The project received an award by the National Education Committee and the technique is now taught at training courses and used in the endemic area of several provinces.
- A study aiming to improve and consolidate snail control in high-transmission areas indicated means to significantly reduce prevalence and was affirmed as a key to control in such settings (Zhuo et al, 1998). The approach was worked out by Zuo Shangjiong et al. at the Hunan Institute of Parasitic Diseases and included construction of storage dams, surrounding fish ponds constructed on the beaches with high nets, building of platforms on the embankments, tree plantations on reed beaches and other measures.

  Detection of circulating *S. japonicum* antigens with enzyme immuno-assay (ELISA) kits, developed at the Sichuan Institute of Parasitic Diseases by Wang Xiuzhen and colleagues, showed high sensitivity and specificity, both in laboratory experiments and in field trials (Wang, 1999).After comparative tests at two national workshops the sensitivity and specificity of this technique was judged to be better than most others resulting in its widespread use on a large scale.
- Jiang Shunde et al. at the Yugan Station of Schistosomiasis Control, Jiangxi Province compared cost-effectiveness of mass chemotherapy vs. chemotherapy identified by inquiry and proved that the latter is a simple, cost-

effective method which could replace mass chemotherapy as a strategy in highly endemic areas (Jiang et al, 1999).

- Xu Guangu et al. at the Duchang Station of Schistosomiasis Control, Jiangxi province studied cost-effectiveness of stratified chemotherapy, with the natural village as the unit, in a heavily endemic areas of Poyang lake (Xu et al, 1998). The approach proved valuable and feasible and could provide a cost-effective method for mass chemotherapy.

Many projects have spawned techniques and approaches, not yet introduced and incorporated in current control activities but which show great promise for future integration. Examples include:

- A health education approach for primary schools based on the inclusion in the teaching of daily activities related to schistosomiasis control, which was devised by Jiang Zhe and his research group at the Nantong Office of Schistosomiasis Control, Jiangsu Province (Jiang et al, 1998). Feasibility studies have been promising and by making schistosomiasis part of the subjects studied by high-grade pupils in schools situated in the endemic areas extra costs for training and information can be avoided.
- A systematic investigation of the social factors influencing schistosomiasis transmission in the area of minority nationalities, carried out at the Yunnan University by Zuo Yangxian and coworkers. The research group reported that knowledge and attitudes, water contact habits, disposal of feces and mass chemotherapy were all important in relation to transmission of schistosomiasis (Zhuo et al, 1997).
- A study of the impact of health education on self-diagnosis, carried out by Liu Qunhua et al. at the Sichuan Institute of Parasitic Diseases. The researchers found that the intervention methods must suit the local conditions but correctly thought health education would indeed lead to a better proportion of infected individuals seeking treatment (Liu et al, 1994).
- An antibody assay based on *S. japonicum* egg antigens and monoclonal antibodies which was shown to reverse from positive to negative in more than 90% of cured subjects in 18 months or less (Hua et al,1996). The test was developed in the Jiangsu Institute of Parasitic Diseases by Zhu Yinchang and

colleagues who found it superior to most commonly used assays which do not show reversal in more than 40% of treated patients within the same time period.

- A dot immunogold filtration assay which, developed in the Zhejiang Institute of Parasitic Diseases by Gan Xiaoxian et al., which was shown to be a simple, sensitive and specific assay, yet rapid, convenient and requiring no special equipment (Ding et al, 1998).
- An analysis of three approaches for schistosomiasis control of farm animals in heavily endemic areas on the Poyang lake shore, done by Yu Lushan and coworkers at the Jiangxi Agriculture University. The cost/benefit ratios at different prevalence levels indicated that selective chemotherapy would be preferable at a prevalence less than 45%, while mass chemotherapy should be chosen if the prevalence was higher (Yu et al, 1996).
- A study of compliance comparing two different strategies of mass and selection chemotherapy in highly endemic areas, carried out by Guo Jiagang et al. at the Shanghai Institute of Parasitic Diseases, highlighting factors of importance for compliance, e.g. the best time of year for chemotherapy is when agriculture and fishing demand the least attention (Guo et al, 1999).
- A cost/benefit investigation of two mass chemotherapy approaches to control schistosomiasis in man and cattle in heavily endemic areas, carried out by Wang Zaihua and colleagues at the Hubei Institute of Parasitic Diseases. They evaluated the sequence and interval of mass chemotherapy and arrived at results showing the superiority of an interval method of mass chemotherapy (Wang et al, 1998).
- Designs to keep snails out of dams based on a combination of water/sand dynamics and snail biology and ecology. A patent was granted for one of the techniques which was developed at the Hubei Institute of Parasitic Diseases by Yang Xianxiang et al. (Yang et al, 1994) and the approach is now at the heart of a long-term study to control snails spreading with river irrigation systems.
- The observation, reported by Wu Xin et al. at the Yunnan Centre for Schistosomiasis Control, that that infectious snails appear and disappear according to season. There is only one transmission season in the Yunnan mountainous areas and the density of infected snails seems to be low in May and then increases rapidly in August to peak around October (Wu et al, 1995).

- The development of a new molluscicide as efficacious as niclosamide by Shi Tianyi and his group at the Hunan Institute of Parasitic Diseases (Zhang et al, 1994). The PI was awarded a patent from the China National Patent Bureau and given the second-grade award for 'Advances in Science and Technology' in the Hunan Province. However, it was also realized that a more efficient, less costly production process would be needed to make the new compound practically useful. Research on the relationship between schistosomiasis and viral hepatitis by Chen Zhi et al. at the Zhejiang Institute of Parasitic Diseases which provided reference indicators to distinguish between the origins of liver damage, thereby facilitating the correct diagnosis of advanced cases due to schistosomiasis (Wang, 1995).

7.6 Workshops

A number of workshops were held in various parts of the country, some wholly sponsored by JRMC and some held in collaboration with other sponsors such as MOH and TDR (Table 20). The workshops addressed all the operational research priority areas and four workshops were devoted to communication skills and proposal development. Experts from TDR and Chinese scientists lectured and held sessions directly with investigators help them to better formulate their proposals and to improve their ability to select suitable study topics, design and assess research and outcomes. As a result of the workshops, researchers both from provincial institutions and 'grass-root' stations upgraded their skills in study design and methodology. Collaborative research between institutions was encouraged and new fields were pioneered and explored, e.g. how to evaluate the effect of health education and cost-effectiveness analysis for different strategies. The quality of proposals was improved after the workshops which included analysis and revision face to face with the scientists involved.

The first workshop was planned as a satellite to a TDR-sponsored international symposium on molecular biology held in 1993 in Nanjing City, Jiangsu Province (Brindley, 1995). Among other important workshops that on serodiagnosis for schistosomiasis in China, held in Yueyang City, Hunan Province should be mentioned as it played an important role in promoting and supporting the development of this field. The last workshop, focused on the rapidly emerging technology of Geographical Information System (GIS), was held in 1998 in Jiangsu

Provincial Institute of Parasitology in Wuxi. This activity was partly supported by TDR and included experts from the US institutions of CDC, NASA and ESRI. As a result dedicated GIS computer software and equipment were supplied to each province.

Table 20 Training workshops

Training workshops[a]	
Control strategies	*Operational research*
Epidemiology and control strategies	Economics of operational research
Information management, role of computer	Cost-effectiveness analysis
Health education methodologies	Outcome of health education
Update on vaccine development	Role of surveillance
Assessment techniques	*Project evaluation*
Technical introduction	Role of health education
Assessment procedures	Diagnostic issues
Indicators	Dummy analysis of project designs
Cost/benefit analysis	Case study: review of a real project
Role of immunodiagnosis	*Geographical Information Systems*
Review of advances in serodiagnosis	Global Positioning Systems
Surveillance and evaluation of cure	The ArcView GIS approach
Sensitivity, specificity and predictive values	Remote Sensing Analysis

[a]Workshops organized by JRMC from 1992 to 1998. In addition, one workshop (held in 1995) was devoted to a mid-term evaluation of the work of JRMC.

7.7 Training

JRMC did not only provide funds for operational research but also emphasized training with the aim of enhancing the professional culture among national scientists. A large number of young scientists have been educated and trained and are already playing an important role in schistosomiasis control and research. Broadened perspectives and an enlarged knowledge lead to an overall improved ability to select useful topics for research. Science plays a key role in productivity and younger scientists who were given an important role will undoubtedly benefit schistosomiasis control and research in China in years to come. More than 20 young qualified researchers were sent abroad for advanced studies (Table 21), an investment that proved worthwhile as most of them initiated operational research after completing their course. The JRMC-sponsored workshops and symposia promoted communication with outside scientists leading to an improved capability in project design. Five researchers were directly supported by TDR within the framework of the World Bank loan program to do further studies, while one accomplished an analysis of the cost-effectiveness of schistosomiasis control in China at the Swiss Tropical Institute. The results and analysis showed that mass chemotherapy could be used when the prevalence is more than 44%, while selective chemotherapy should be chosen when the prevalence is less than that (Guo et al, 1998).

Table 21 Distribution of training activities

Distribution of training activities[a]

Discipline	Number	Place of training
Epidemiology	9	Japan, Sweden, The Philippines, USA
GIS	4	USA
Health economy	2	Thailand
Health education	2	The Philippines, USA
Immunodiagnosis	4	UK, USA
Public health	2	Switzerland, USA
Total	23	

[a] Individuals sent abroad for more than 6 months of training.

7.8 International and intersectional collaboration

JRMC activities involved collaboration between a large number of institutions and public health authorities within the country. The 245 research proposals approved emanated from more than 50 institutions and included more than 1,000 researchers, while the workshops and symposia held were attended by approximately 200 persons from many different provinces. Operations also involved international cooperation and the cooperation between TDR and JRMC was especially important in assessing the proposals, while the training of younger scientists was greatly enhanced by including the Swiss Tropical Institute, Basel, Switzerland and the Leopold II Institute for Tropical Medicine, Antwerp, Belgium, in the network. For example, a public health workshop was organized in Basel at which 16 staff members from eight provinces were trained in epidemiology, management, statistics, health economics and computer techniques. The scientific exchanges and training visits that JRMC organized provided opportunities for contacts outside China and a chance for scientists to learn and understand each other more deeply. This opened up promising prospects for international cooperation in schistosomiasis control in the future.

JRMC brought managers and schistosomiasis experts together with scientists and experts on health economics, social medicine and health education. Research on control expanded by the importation of methods, views and knowledge from related fields. For example, the special skills of health education are now applied in schistosomiasis control and research on cost-effectiveness of control strategies has helped utilize health resources to increasing the economic effect and efficiency of control. The mix of skills introduced interacted to enrich policy and practice in research management and, overall, this arrangement has proven to be suitable for the Chinese situation as shown by the JRMC experience over the past 7 years. The way JRMC was structured and its method of reviewing and revising schistosomiasis operational research proposals including the follow-up evaluation of funded projects has proved an excellent mechanism for managing the research agenda. JRMC has organized nationwide cooperative research on common problems for policy, management and methods in schistosomiasis control. Examples include the establishment of a 'National Reference Center for Immuno-diagnosis' and a cost-benefit analysis of the control strategies applied in high endemic areas. The optimization of control outcomes and improvement of efficiency was shown to be dependent on such national cooperation at various levels.

7.9 Conclusions

Control of schistosomiasis (or any other infectious disease) must be based on sound scientific information. JRMC promoted a strong development in this direction by functioning as the operational research arm of the consolidated effort to eliminate schistosomiasis as a public health problem. In retrospect, it is obvious that the IDA loan not only contributed substantially to the rapid reduction of both prevalence and intensity of *S. japonicum* infection in humans and animals throughout the endemic areas of China but also strengthened the research potential. Data and methodology emanating from international research were successfully grafted onto the body of emerging information based on the national experience of schistosomiasis control accumulated over 50 years. JRMC focused on projects where there were reasons to believe that results would be forthcoming 'here and now' rather than in the distant future. For this reason, drug development was preferred over vaccine research and, in the field of immunodiagnosis, development and production of kits were favored over research on new diagnostic antigens. In addition, epidemiology, surveillance systems, and GIS-related research received strong support.

The improved situation in the field is clearly due to the reduction of morbidity through increased availability of praziquantel. Less visible, but of crucial importance, is the influence of research modernization and the improved capacity for high-level studies. The increased interest in research reflects the important role of JRMC and the sustained input from TDR in mobilizing and galvanizing scientists working in academic institutions and staff directly engaged in control activities. Comparative investigations and proper validation of approaches in different settings (treatment, diagnostics, cost effective analysis, etc.) have been introduced. Without doubt this has contributed to the appearance of new Chinese concepts in regard to biomedical science, particularly in epidemiology, and to the penetration of scientific thinking into control activities. The research level in the country has improved and the training activities have added special skills and broader research collaboration. Specifically, a serum bank has been established and the surveillance of progress has provided reliable data on the distribution of infected humans, snails and also animals. Control in areas of low endemicity presents additional research needs of prime importance for reaching the goal of elimination of schistosomiasis as a public health problem. At this time progress towards elimination will move into focus presenting new challenges. So far, there is little experience of cost-effective management of control strategies in low-endemicity areas, and China's experience in this connection is likely to be useful on a broader (international) scale. Strengthening of research institutions, especially in operational research on cost-effective methods of disease control, is a high priority in view of rapidly changing technologies and strategies. JRMC's legacy will be a much improved network for schistosomiasis control in China and the control program will benefit further as its young researchers mature as scientists.

The progress would surely not have been so impressive without the creative and enthusiastic work of numerous professionals throughout the Chinese schistosomiasis network but there is still much work to do. For example, experience in preparing competitive research proposals is generally lacking and, although the country already has a large number of researchers in biomedical sciences trained in the latest techniques, there is still a need for skilled social scientists, health economists, and specialists in organization and management issues. Continued input and strengthened international collaboration after the end of the project is of utmost importance to ensure maintenance of goals achieved and consolidation of results obtained.

While it has been shown, both in China and elsewhere, that the pathological manifestations of schistosomiasis can be kept at bay through continuous drug treatment schedules, the notion of promoting a more long-term effect through parallel research activities, has been at the heart of the current experience. Apart from being responsible for research and training, JRMC also was involved in the implementation of new findings for control. New strategies for schistosomiasis control were tested, validated and, in some cases, incorporated in ongoing control efforts. Although the road from 'bench to field' is often taxing and slow, which proved true also in China, a surprisingly rapid transfer of new control approaches actually took place. This may well be due to the fact that the ranks of JRMC included senior managers and technical experts for schistosomiasis control as well as scientists with expertise in health economics, social medicine and health education. In fact, the interdisciplinary approach characterizing JRMC led to an expansion of the expertise utilized in schistosomiasis control adding views and knowledge from related fields. This, in its turn, contributed to a change from the traditional strong focus on biology to include also other fields leading to a broadening of approach, e.g. research on the cost-effectiveness of control strategies has helped to utilize health resources better and, after the implementation of the economic system reform in the rural areas, new technologies and control methods, more suitable for a developing market economy, have been explored. Pioneering of novel methods in health education proved useful in establishing integrative indicators and a system of evaluation of the effectiveness of control due to a better collaboration between social medicine experts and health educators. Taking into account the recent changes in the Chinese society, JRMC contributed effectively to a move away from the health propaganda of classical health education towards a concept of interactive communication (IEC). This concept will undoubtedly increase social and individual participation improving compliance.

The outcome of the World Bank initiative is deemed as very positive and the experience gained in China is likely to be of benefit on the international as well as the national level. However, it should also be admitted that progress might have been more swift, had there been a more close interaction between the control activities and the research efforts. In addition, progress was hampered in some of the participating provinces due to slow and uneven internal distribution of funds which seriously constrained the overall programme. While the basic strategy of control has been defined for areas of high, medium, and low endemicity, problems will without doubt arise in the implementation phase. Since the transmission situation has not been fundamentally changed anywhere, re-infection of inhabitants and livestock is inevitable. Research will be required to formulate appropriate changes and improvements in control techniques in different epidemiological situations. Some problems are relevant mainly to individual provinces, while others are of a national importance. The time during which JRMC was active was a period of important changes in China. The work carried out has been a good start for the introduction of action-oriented basic and applied research in China, which will, without doubt, prove beneficial also for other sectors. Thus, not only health will benefit from the JRMC experience at the scientific managerial and partnership level.

8 A Basic Study on the Importance of Bovines for Human *Schistosoma japonicum* Infections around Poyang Lake, China

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8.1 Abstract

We hypothesize that bovine infections are responsible for the persistence of human schistosomiasis transmission in the Yangtze marshlands of China. To test this hypothesis, we are carrying out a comparative intervention among four administrative villages in the Poyang Lake region, Jiangxi Province, two of which are experimental and two are control. The primary design involves treating, at the onset of the study, all the inhabitants in all four villages with praziquantel and all the bovines in two villages (the experimental or intervention villages). Following treatment, rates of reinfection in people of all villages, and in bovines in the experimental villages, will be assessed as will the ongoing prevalence of infection in bovines in the control villages. Before treatment, the prevalence and intensity of infection among humans and bovines was ascertained in the four villages. Our study design and baseline information are presented here, along with a description of the ecology of the study villages.

8.2 Introduction

Currently, 0.9 million people are infected with the Oriental schistosome, *Schistosoma japonicum*, in areas situated primarily along the middle and upper reaches of the Yangtze River. (Li et al., 2000b) Within China, the Poyang Lake region represents one of the last strongholds for schistosomiasis in the marshland ecotype. According to the 1995 province-wide sampling survey, 1,125 villages were endemic with an underlying human prevalence ranging from 5% to 30%. (Anonymous, 1997) Among the hyper-endemic communities, the bovine (cattle and water buffaloes) prevalence was approximately 13%. Although the infection rate of cattle was reported to be a little higher than that of water buffaloes, the latter (220,000 animals) are ten times more numerous. Moreover, the survey revealed that more than 90% of schistosome eggs in the flood plains were excreted by buffaloes. It is noteworthy that the average stool weight of cattle per day (estimated to be 25 kg) is 100 times that of humans (250 g). Buffaloes produce 50-60 kg of stool per day.

Given this evidence, we hypothesize that bovines, especially buffaloes, are responsible for the persistence of human schistosome transmission in the Yangtze marshland region where endemic schistosomiasis remains uncontrolled. Since 1992, praziquantel has been used repeatedly as chemotherapy following World Bank-

Chinese Schistosomiasis Control Program guidelines, yet infection remains stubbornly above a prevalence of 5% (Jiang et al, 1996; Lin et al,, 1997a). Control of snails is not possible due to the large areas of lakeside marshland involved and the inability to manipulate the environment as has occurred in other areas of China where control has been achieved (Sleigh et al, 1998a, b, c), The chemotherapy program in the marshland areas is focused on human populations. Animal treatment is attempted but is much more difficult to accomplish for routine control. Although praziquantel works well on cattle and buffaloes they are difficult to reach for treatment, their water exposure remains substantial and unaltered, their worm burdens are often very high, and their population changes frequently due to a high birth rate (> 10% per year) and trading of animals from one area to another (-- 10% per year). Thus, routine chemotherapy programs for bovines have achieved limited coverage (< 50%) and limited success. At present, chemotherapy is supplied biannually to both humans and bovines in areas with persisting moderate human prevalence of infection (5-15%) and less frequently in areas of lower prevalence (Ross et al, 1997a).

A National Institutes of Health-funded Tropical Medicine Research Centre (TMRC), based at the Institute of Parasitic Diseases in Shanghai, is developing and testing anti-schistosome vaccines for buffaloes (Liu et al, 1997; McManus, 1999) As part of the TMRC program, the project described here, was designed to measure and mathematically model the importance of buffaloes in transmission of schistosomiasis to humans. This information will be vital when it is time to field test buffalo vaccines and it will also connect with ongoing research on *Oncomelania* snail dynamics.

We chose four administrative villages for the study: two as experimental areas (intervention) and two as control areas (an administrative village may have two or more natural villages). The design involved treating, at the onset of the study, all the inhabitants in all four villages with praziquantel and all the buffaloes/cattle in two villages (the experimental villages). Before treatment, the prevalence of infection in humans, bovines, and snails was established. After treatment, rates of re-infection in people of all villages, and in bovines in the experimental villages are being assessed as well as the ongoing prevalence of infection in bovines in the control villages. If our hypothesis on the importance of bovines is correct, reductions of infection in bovines will reduce snail infection and substantially decrease human transmission. Here we present the 1998-1999 cross-sectional baseline epidemiologic data for the four study villages. A companion paper (Davis et al, 2002) describes the snail sampling procedures used to assess the ecology, density, and distribution of infected *Oncomelania* snails in the four villages using geographic information systems (GIS) and remote sensing technology. Subsequent articles will discuss the longitudinal data and mathematically model the modes of bovine transmission for three years after the baseline survey.

8.3 Materials and Methods

Study areas

Four selected administrative village communities (introduced in Davis and others (Davis et al, 1999); see also Davis and others (Davis et al, 2002) around Poyang Lake in Jiangxi Province were divided into two groups: two intervention (experimental) villages (bovines treated with praziquantel) and two control villages (bovines not treated). The intervention villages comprised Jishan Administrative Village in Yongxiu county, and Dahuang Administrative Village in Duchang county. The control areas comprised Xinhua Administrative Village in Xinzi county and Hexi Administrative Village in Yongxiu county. The GIS-facilitated maps of Poyang Lake showing the localities of the four villages are presented in Figures 13 and 14 in Davis et al. (1999).

Dahuang Administrative Village, consisting of 12 natural villages, is situated in the northeastern sector of Poyang Lake. The total population at the commencement of the study was 2,299, with most working in either the agricultural or fishing industry. The main agricultural products are rice, sweet potatoes, peanuts, and beans. The villages are adjacent to the lakeshore and marshland and residents contact potentially endemic waters primarily through occupation or daily activity. In the dry season, bovines graze on the marshlands. Pigs are raised within pigsties throughout the year. Since 1992, regular control measures have been taken by the local schistosomiasis station. In 1997, the positive rate for schistosomiasis by indirect hemagglutination assay among residents was 30% (401 of 1,335). As a result, mass chemotherapy was carried out in three of the natural villages and selective treatment in the remainder. The density of positive snails was recorded in 1990 at 0.026/m2. It is noteworthy that Dahuang is the smallest of the four administrative villages in the study and differs from the other three in that there are no buffalo here, only cattle (numbering 168 in total) grazing on 0.35 km2 of land.

Jishan, consisting of eight natural villages, is located on Jishan island (5 km2 in area) in the western sector of Poyang Lake. It is a typical heavy endemic area and had a total population of 2,017 at the commencement of the study. On the west side of the island, there are large areas of snail infested marshland. Serious flooding occurred on the island in 1998 and 1999, which caused the evacuation of three whole villages. There are approximately 1,000 residents in the remaining four villages. Approximately 30% of the residents (mainly young people) work off the island for extended periods of time and thus only 600 villagers are exposed to infection by *S. japonicum*. Forty-six percent of the population is engaged in agricultural activities while the remaining individuals split their time between agricultural and fishing activities. There are 665 buffaloes on the island, but this number tends to fluctuate due to the buying, selling, death, and birth of individual animals. The entire grazing range is 12.1 km2, the largest of the four study areas. According to epidemiologic data collected in 1996, 17% of the residents and 20% of the buffaloes were infected with S.japonicum, despite annual mass chemotherapy.

Xinhua, consisting of 19 natural villages, is situated in the northwestern sector of Poyang Lake. The total population is estimated to be 1,000 residents, with most engaged in either agriculture or fishing. All households raise pigs (- 500 head) in pigsties, but buffalo (168) usually graze on the marshlands. Selective chemotherapy was administered to residents who were either stool-positive for eggs, or presenting with symptoms and signs associated with disease in 1995. In 1997, the prevalence among residents and bovines was 8% (42 of 500) and 18% (6 of 34), respectively. There are approximately 1.18 km2 of grazing land and 267 ~ 104 m2 of snail-ridden area.

Hexi, consisting of six natural villages, is located on Hexilong Island in the western sector of Poyang Lake. There are 1,060 residents living on the island but one-third of them usually migrate for temporary work. Like the other study communities, the main daily activities of residents involves agriculture and fishing. One of the villages is situated only 20 meters from the marshland while the remaining five are 200-500 meters away. This island was also heavily hit by floods in 1998-1999, which forced the migration of many families from the island. The total grazing area (3.69 km2) ranks second among the four communities surveyed. There are 364 buffaloes on the island and all pigs are housed in pigsties.

Hexi and Jishan villages are similar in ecologic complexity and thus are well paired as control and experimental villages; the same holds true for the smaller villages (in area) of Dahuang and Xinhua.(Davis et al., 2002)

Study design

The field study commenced in late 1998 and will last three years. The overall study design is shown in Figure 18. All residents aged five to greater than 60 years of age in the four administrative villages were treated and cured at the commencement of the study. The at-risk population is being followed for three years (over six transmission periods) to measure exposure to water at snail-infection sites and to determine the incidence and intensity of re-infection. At the end of the first, second, and third years of the study, all those re-infected are to be treated. All bovines in the intervention areas were treated and cured of infection at the start of the study and 12 and 24 months later. By comparing human infection incidence and serial snail infection rate in the bovine-treated and bovine-untreated communities, the importance of infected buffaloes in disease transmission will be determined.

At baseline a medical questionnaire was administered to all study participants. The questionnaire included items such as ethnographic background, disease history, and history of water contact outside the dikes that surround the lake. This was followed by a stool survey on a random age-sex stratified sample of the at-risk population, defined as any persons reporting on the questionnaire any contact with water in Poyang Lake. This permitted us to efficiently estimate the pretreatment prevalence of infection in each study area. We collected stools from approximately 20 males and 20 females chosen at random from the at-risk list for each of 7 age groups in each village (5-9, 10-14, 15-19, 20-29, 30-39, 40-49, 50-60, and > 60 years). The samples (Table 22) numbered approximately 280 persons per village, except for Xinhua where we performed the stool survey on almost the entire population to complete a previous study of schistosomiasis in that area.

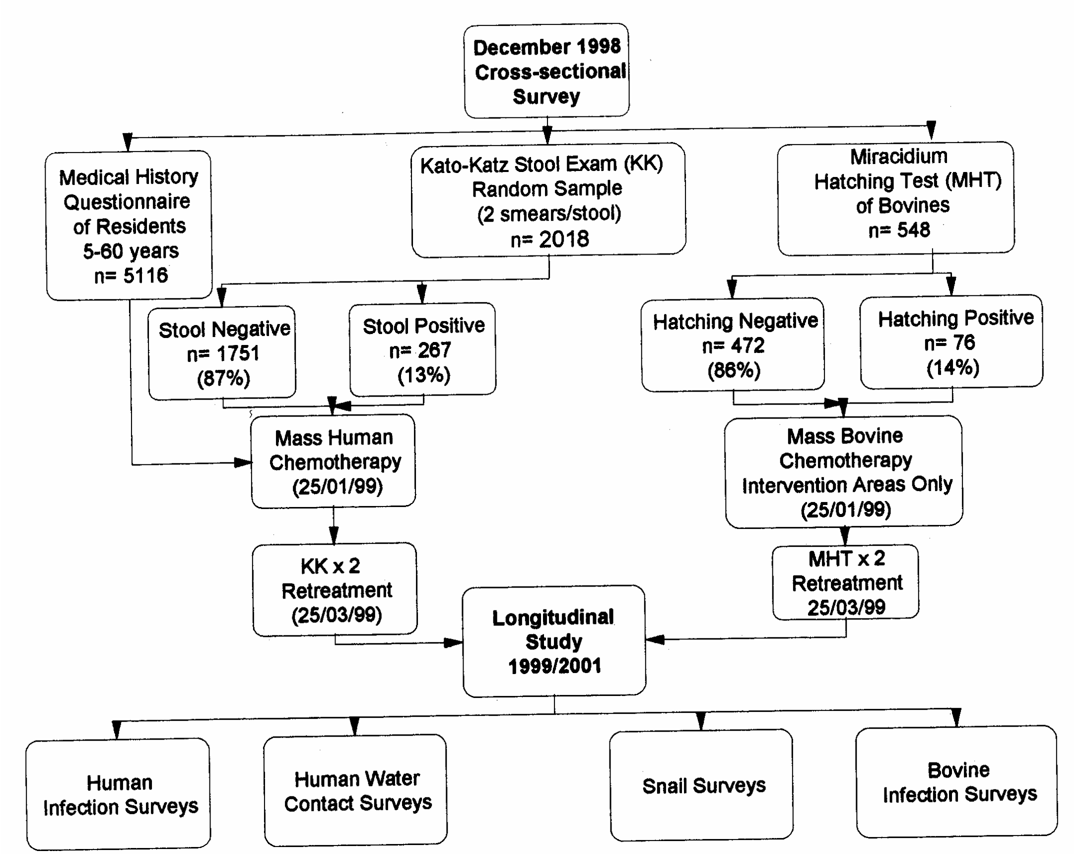

Figure 18 Flow diagram illustrating the procedures carried out in the 1998-1999 cross-sectional survey and their resulting epidemiological outcomes. Also depicted are the additional studies planned for the subsequent years.

Each pretreatment stool examination included two 41 mg of Kato-Katz (KK) smears obtained from one stool specimen per person. The whole population in all study areas was then treated with praziquantel (40 mg/kg) and one month later the subset known to be at risk of infection was rechecked again for persisting infection (one stool, 3 KK smears/person). If still infected (at least one positive smear), they were re-treated and checked again one month later (one stool, 3 KK smears). No individual required a third baseline treatment. We thus efficiently obtained estimates of baseline (pretreatment) infection prevalence (one stool, 2 smears, all age-sex groups in a random sample of those at risk). Furthermore, we efficiently demonstrated that all people were uninfected after treatment at the start of our ongoing longitudinal estimate of re-infection (3-5 negative smears per person in a total of 2 stools with at least the last 3 smears all negative).

Table 22 Distribution of uninfected and infected individuals

Distribution of uninfected and infected individuals within study villages*

Village	Uninfected† (n = 1,751)		Infected (eggs/g) 12–100 epg (n = 185)		101–400 epg (n = 58)		>400 epg (n = 24)	
	0 epg n	%	n	%	n	%	n	%
Jishan	228	80	45	16	12	4	1	0.3
Dahuang	243	87	26	9	6	2	4	1
Xinhua	1,026	88	88	7	37	3	17	1
Hexi	254	89	26	9	3	1	2	0.7

* epg = egg per gram (of feces).
† Those egg-negative for *Schistosoma japonicum* by the Kato-Katz thick smear stool examination.

After completion of the stool surveys, human activity diaries are completed annually for the entire at-risk human population during the spring (May-June) and fall (October) transmission periods. Approximately 200 residents from each village are completing the activity diaries. Local doctors and teachers are visiting each study participant and writing the records twice a week. The activity diary questions include the location, frequency, duration, time of day, and body part immersed for each contact with water.

Table 23 Prevalence and intensity of *Schistosoma japonicum* infection in the human population by age and sex

Characteristics of the combined human population according to age, sex, prevalence, and intensity of *Schistosoma japonicum* infection

Age group (years)	Males n	% Infected	GM*	Females n	% Infected	GM*	Total n	% Infected	GM*
5–9	101	12	582	70	13	399	171	12	503
10–14	231	20	121	174	13	227	405	17	156
15–19	115	19	75	69	13	145	184	17	96
20–29	112	17	153	118	12	107	230	14	134
30–39	136	13	33	186	11	192	322	12	118
40–49	167	15	79	198	7	67	365	10	75
50–60	168	12	202	160	9	32	328	10	132
>60	10	20	54	3	0	0	13	15	54
Total	1,040	16	145	978	11	165	2,018	13	153

* GM = geometric mean egg counts/gram of stool for infected individuals.

A list of the age, sex, identification, and owner of each bovine in the four administrative villages under study was also obtained. From the list, a random sample of males (15) and females (15) in each of the following three age groups was obtained: < 1 year, 1-3 years, and > 3 years. This gave a total of -- 90 buffaloes per village, except for Dahuang, where nearly all of the cattle (152 of 182) were tested. For each bovine included in the sample, a fresh stool specimen (-- 200 g) was obtained and a 50-60 g sub-sample was taken for a miracidial hatching test (MHT). Hatching was done at optimal temperature (24-28^{o}C), achieved by pre-heating the room where the MHT was to be performed and monitoring it by thermometer Any bovines identified as positive by MHT had 50 g of the unused portion of their original stool sample subjected to an egg count procedure, with the stool suspended in the water and passed through sieves to remove fiber (mesh sizes of 30 and 150 per inch) and then suspended in a nylon bag that captures the eggs in the sediment, which on resuspension was examined and counted by a standard method to calculate number of the eggs per gram (epg) (of feces) for all positive buffaloes.

The snail survey sampling methods have been given in detail in Davis and colleagues (Davis et al, 2002). Briefly, using topographic maps, a series of 10,000 m2 areas (called squares) was selected from representative areas of the grazing range of each village. Twenty 100 m2 units (areas) were chosen at random from the 100 such numbered areas in each square. All snails were collected from a 4 m2 frame placed in the center of each unit. The snails were scored for living and dead; all living snails are crashed to determine the number infected with *S. japonicum* and with non-japonicum trematodes. A GPS (geographic positioning system) record was made to provide exact coordinates for each frame. The GPS data are used in conjunction with remote sensing satellite images to provide precise mapping of localities. Collections are made twice a year, in the spring before the annual flood and in the fall after the floods have subsided, The percentage of grazing land with and without snails is then calculated. The data permit assessing the distribution of infected snails relative to bovine and human behavior through time.

Ethical approval

Written ethical approval for this study was obtained from the National Institutes of Health (Bethesda, MD) and at the national, provincial, and district level within the People's Republic of China. Oral informed consent was obtained from all adult subjects and from the parents or guardians of minors. Study participants identified as stool egg-positive for schistosomiasis were treated with 40 mg/kg of praziquantel, which is the current dosage recommended by the World Health Organization. One month after the initial treatment all treated subjects and bovines (20 mg/kg) were re-examined and retreated if positive.

Statistical analysis

SPSS version 9.0 for Windows (SPSS, Inc., Chicago, IL) was used for further statistical processing. The intensity of infection of infected groups was expressed as geometric mean egg counts per gram of stool. For whole populations the geometric means were calculated using a log (n + 1) transformation. The chi-square test was used to evaluate differences between relative frequencies. The Student's t-test or analysis of variance were used to detect differences between group means. The minimum level considered for statistical significance was set at $P < 0.05$.

8.4 Results

Population descriptors

A medical questionnaire was administered to 5,116 (Dahuang = 1,170, Hexi = 1,063, Jishan = 778, and Xinhua = 2,105) individuals (52% male, mean age = 29 years) in their homes. Forty percent of the sample reported at least a primary level of education with most (44%) engaged in fishing. Seventy-five percent of the study participants stated that they had been previously diagnosed with schistosomiasis, but only 2% ever had advanced clinical features defined as dwarfism, ascites, splenomegaly, or hematemesis. The subjects were treated an average of three times in the past, with 47% having been treated in the previous two years. Other symptoms commonly reported over the previous two weeks were diarrhea (15%), general weakness (10%), and fever (7%). Fifty-four percent of the population reported weekly water contact and 65% stated frequent flood water contact during the 1998 storms.

Human prevalence and intensity of infection

Table 23 shows the prevalence and intensity of infection of the human population. In general, 13% were infected, with a geometric mean (GM) intensity of 153 epg. The highest prevalence and intensities were evident in the younger (< 15 years old) age groups. There were statistically significant ($P < 0.001$) differences between the sexes for prevalence but not intensity. Males were more likely to be infected (16% versus 11%) but their infections were not as severe (145 epg versus 165 epg). When the four study communities were classified according to the percent uninfected, lightly infected (12-100 epg), moderately infected (101-400 epg), and heavily infected (> 400 epg) with *S. japonicum*, the distribution patterns for uninfected and infected individuals were similar. Most of the tested study population was uninfected (80% in Jishan, 87% in Dahuang, 88% in Xinhua, and 89% in Hexi). Lightly infected individuals were the next largest group (16% in Jishan, 9% in Dahuang, 7% in Xinhua, and 9% in Hexi), followed by moderately infected individuals (4% in Jishan, 2% in Dahuang, 3% in Xinhua, and 1% in Hexi). Only a small percentage were heavily infected (0.3% in Jishan, 1% in Dahuang, 1% in Xinhua, and 0.7% in Hexi). The intensity profiles of the respective villages varied significantly (P < 0.027) from each other (Table 22).

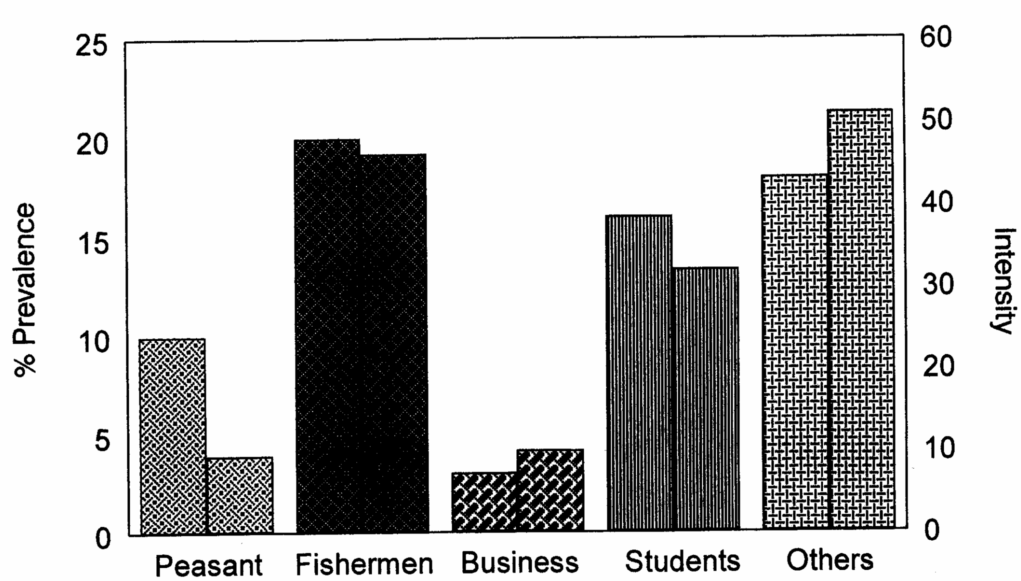

Figure 19 Prevalence and intensity (geometric mean log egg intensity/gm) of *Schistosoma japonicum* grouped by occupation in the four surveyed administrative villages

Human exposure

Although 54% of the study population reported weekly water contact, only 24% of the residents of Xinhua reported such contact. This outcome was statistically different (P < 0.0001) from that reported for Hexi (70%), Jishan (70%), and Dahuang (74%). Among occupational groups (Figure 19), fishermen have the highest prevalence and intensity of infection among the communities. Those categorized as "other" were also heavily infected and thus this group needs to be investigated further. Mode (activity) of water contact was also found to vary significantly (P < 0.0001) among the study communities. Figure 19 shows that fishing is the primary activity on the two island administrative villages (Hexi and Jishan), while collecting firewood near pools of water was the common mode of exposure in Xinhua and Dahuang.

Bovine prevalence and intensity of infection

Table 24 shows the prevalence and intensity of the sampled bovine population. In general, 14% of the tested bovines were infected with a GM intensity of

42 epg. The highest prevalence (27%) was found among bovines 6-12 months old, while the highest GM intensity of infection (69 epg) was found among bovines 12-24 months old. There was no statistical difference between the sexes for either prevalence or intensity of infection. However, most (55%) of the infected bovines tested were found in Dahuang village, and this is where all the cattle reside.

Table 24 Prevalence and intensity of *Schistosoma japonicum* infection in the bovine population by age and sex

TABLE 3

Characteristics of the combined bovine population according to age, sex, hatching, and intensity of *Schistosoma japonicum* infection

Age group (months)	Males			Females			Total		
	n	% Hatching*	GM†	n	% Hatching*	GM†	n	% Hatching*	GM†
0–6	32	13	37	43	5	41	75	8	39
6–12	24	38	42	25	16	38	49	27	41
12–24	40	3	46	40	10	75	80	6	69
24–36	14	67	18	42	19	47	56	16	44
36–48	13	15	3	33	12	60	46	13	41
48–60	14	21	27	30	17	37	44	18	33
60–72	8	0	0	31	19	28	39	15	27
72–84	8	25	23	20	10	13	28	14	17
84–96	15	13	40	43	19	50	58	17	47
>96	17	12	113	56	13	35	73	12	52
Total	185	14	40	363	14	43	548	14	42

* % Hatching = percent miracidia hatching from stool.
† GM = geometric mean egg counts/gram of stool for infected bovines.

8.5 Discussion

Schistosomiasis in the Yangtze River basin remains one of the last strongholds for this disease in China despite 40 years of concerted control efforts by the government. Chemotherapy has been the cornerstone of most control efforts to date. With the end of the World Bank Loan Schistosomiasis Control Program in 2000 and the completion of the Three Gorges Dam by 2009 it is feared that, with limited financial resources, schistosomiasis will once again become a serious problem in lake and marshland localities. In the Poyang Lake region, mass chemotherapy has been used extensively over the past decade (Jiang et al, 1996; Lin et al, 1997b; Wiest et al, 1994) but the underlying prevalence of human schistosomiasis in the region remains stubbornly well above 5%. A large number of infected bovines and continuing transmission suggest that bovines are a major potential reservoir for schistosomiasis transmission and a threat to eradication programs. To ascertain their actual contribution in the transmission of human schistosomiasis, we initiated a comparative intervention that will help to determine the bovine contribution to human infection.

We have described our study design and baseline data for future reference as the impact of the intervention unfolds. In a subsequent paper, we will report the rates of re-infection in people of all villages, and in the bovines in the intervention villages as well as the serial prevalence estimates for infection of bovines in the control villages. We will then be able to assess the importance of buffaloes and cattle for maintaining transmission of *S. japonicum* in this lake region of China that has been resistant to control for many decades.

9 The Importance of Buffaloes in the Transmission of Schistosomiasis in the Poyang Lake Region

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9.1 Abstract

Schistosoma japonicum transmission in China's marshlands continues despite more than 40 years of control efforts. Snail control is almost impossible and repeated chemotherapy cannot achieve satisfactory reduction in prevalence in many areas. The major problem is that buffaloes are also hosts in the *S. japonicum* life cycle. In order to determine the importance of buffalo infections in maintaining human transmission in China marshland areas, we chose two administrative villages for the study: one experimental (intervention) and the other for control. In both areas all people were treated with praziquantel to eliminate possible schistosome infection at the start and were followed-up for 5 years. Results show that the intervention village experienced a 70% significant reduction in human prevalence, compared to the village without intervention. This effect became apparent by the end of the third year (P=0.027), and was further confirmed at the end of the fourth year (2002; P=0.023). It was also found that the infection rates of buffaloes aged under 3 years were between 2% and 18%, while for those aged above 3 years, it was between 0 and 2.9% in the intervention and control groups, respectively. In 2000, a main problem influencing human prevalence was buffalo trading in the intervention group. Our experiences gained show the difficulty of interrupting buffaloes schistosomiasis transmission.

Key words: Buffalo, Schistosomiasis, chemotherapy

9.2 Introduction

In China, schistosomiasis due to *Schistosoma japonicum* is a major health problem. Great suffering and premature death among people has existed for centuries. Recently, more than 100 million people were at risk of the infection in southern China (Mao and Shao, 1982 and Yuan et al, 1992a,b). The endemic areas are mainly distributed along the Yangtze River and down to the basin of thee River. The high-risk areas are around the middle and lower reaches of the Yangtze River, the Tongting Lake and Poyang Lake. Based on epidemiological pattern, and ecology of the intermediate snail host in endemic areas, the endemic regions can be stratified into three types: plain regions, marshland and lake regions, hilly and mountainous regions. 95% of 3.4 billions square meters of snail habitats are located in the river beaches and lake areas according to national report of 1999 (Guo, 1999).

Two of the largest lakes in China are Poyang Lake (the largest) and Dongting Lake. Both are major areas endemic for *S. japonicum*, but differ insignificantly with regard to schistosome transmission. The great annual floods of the Yangtze affect these lakes in different ways.

The Poyang Lake region represents one of the last strong holds for schistosomiasis in a marshland ecotype. According to the 1995 province-wide sampling survey, among the hyper-endemic communities, the bovine (cattle and water buffaloes) prevalence was approximately 13% (OEDC, 1997a). Poyang Lake in Jiangxi Province is unique. It connects to the Yangtze River by a narrow passage. People live behind dikes, either on islets in the lake basin or outside the basin. The lake is completely surrounded by dikes so that with the annual floods (beginning late May or June, ending in October of November) the lake fills up like a bathtub. At high flood season the lake is an inland sea available only to fishermen. When the flood subsides the lake losses as much as 75% of its water, exposing vast flat marshlands. The marshlands are used for cattle grazing. The epidemiologists of schistosomiasis in the Poyang Lake have described four unique characteristics. 1) Cattle are considered to be responsible for more that 85% of the transmission from snails to other cattle and man in the lake basin. 2) There are no snails living outside the lake basin behind the dikes. 3) All transmission occurs in the lake basin. 4) The annual floods drown snails and presumably the life of the snails is reduced to one year or less (Zhang et al., 1996)

The NIH-funded Tropical Medicine Research Center, based at the National Institute of Parasitic Diseases in Shanghai, in collaboration with scientists from Australia, and USA, has been developing and testing an anti-schistosomal vaccine for buffaloes. The research activity is directed at developing better tools as well as making strategy for control schistosome infection in the marshland.

As part of TMRC program outlines above, the research described here is designed to measure the importance of buffaloes to human transmission. It will lead to a mathematical model of the transmission dynamics for residual schistosome transmission in those areas that has resisted all control efforts so far. This information will help when to do field test of buffalo vaccines, and it will also connect to the research on snail dynamics.

The field study lasted 2 years. All residents aged 5-60 years old in 2 communities in the Poyang Lake known to have high exposure to marshlands or lake transmission of schistosomiasis had been treated and cured. The “high risk” group has been followed for two years (4 transmission seasons) to measure exposure to water at snail-infested sites and determine the incidence and intensity of re-infection. In two communities, choices after baseline indicators of transmission are obtained by the research team in November 1998 before the start of the study. All possibly infected buffaloes were treated with praziquantel annually for two years. By comparing human incidence and serial snail infection in the buffalo-treated and buffalo-untreated communities, we measured the importance of infected buffaloes for snail infection and human transmission.

9.3 Materials and Methods

Study areas

The 2 study villages are divided into two categories, Jishan village as an intervention area (buffaloes were treated) and Hexi village as control area (buffaloes were not treated). A medical questionnaire was administered to 1841(Jishan=778. Hexi=1063) local residents.

Study design

The field study started in late 1998 and lasted for three years. All residents aged five to greater than 60 years in the two administrative villages were treated at the beginning of the study. The at-risk population were followed for three years (six transmission seasons) to measure exposure to water at the snail-infection sites and to determine the incidence and intensity of re-infection. At the end of the first, second, and third year of the study, all re-infected individuals were treated. All buffaloes in the intervention areas were treated at the start of the study and at 12 and 24 months later. By comparing human incidence and serial snail infection rates in the buffalo-treated communities, the importance of infected buffaloes in disease transmission was determined.

Each pre-treatment stool examination included two specimens. 41 mg of faeces for Kato-Katz (KK) smears were obtained from every stool specimen and person. The whole population in all study areas was then treated with praziquantel (40mg/kg) and one month later the subset known to be at risk of infection was rechecked for persisting infections (one stool, 3 smears/person). If still infected (with egg positive smear), they were re-treated and checked again one month later (one stool, 3 smears). No individual required a third baseline treatment.

Additional methods in 2001 and 2002

The result of 2000 showed that the prevalence of schistosomiasis was still high in intervention village. The major problem was that new buffaloes had come to the area (newly bought and new born) which were not treated in time. Some fishermen from Jishan village were staying in harbor closed to Jishan village. In order to reduce the risk of infection from buffaloes, the following additional interventions were made in Jishan village.

- Local doctors were hired to observe the migration of fishermen to Jishan harbor from other places and to give chemotherapy to the newly comers. It was recorded that 9 fishing boats with 22 fishermen came to the harbor in Jishan between July and August. All fishermen were treated after they arrived at Jishan
- All buffaloes in Jishan were re-examined and treatment was given to those positives in early 2001. All newly bought and newborn buffaloes were treated once a month.

9.4 Results

It was found that the prevalence rates in residents and buffaloes were reduced significantly ($P<0.01$) in Jishan Village after intervention of chemotherapy on buffaloes (100% coverage) and residents (100% coverage) in 2001 and 2002, while the situation in the control village, Hexi did not have significant changes. (Figures 20, 21) The geometric mean egg count of residents and bovine was almost in parallel. (Figure 22)

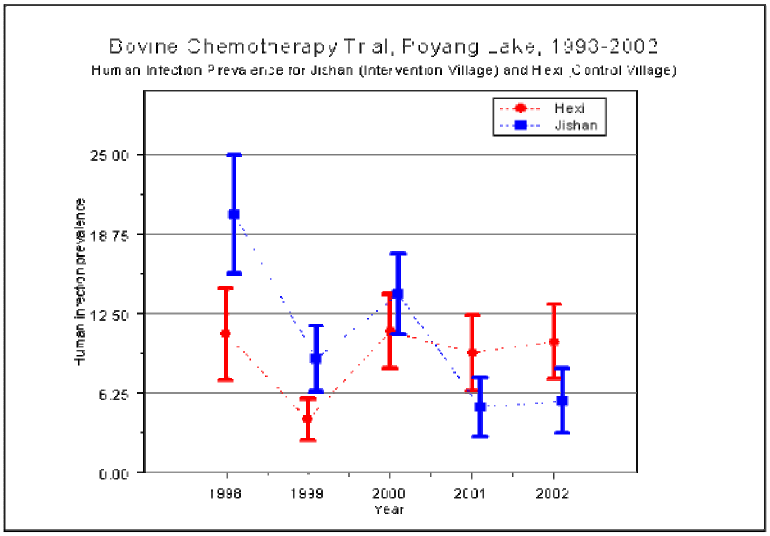

Figure 20 Human schistosomiasis prevalence between 1998 and 2002

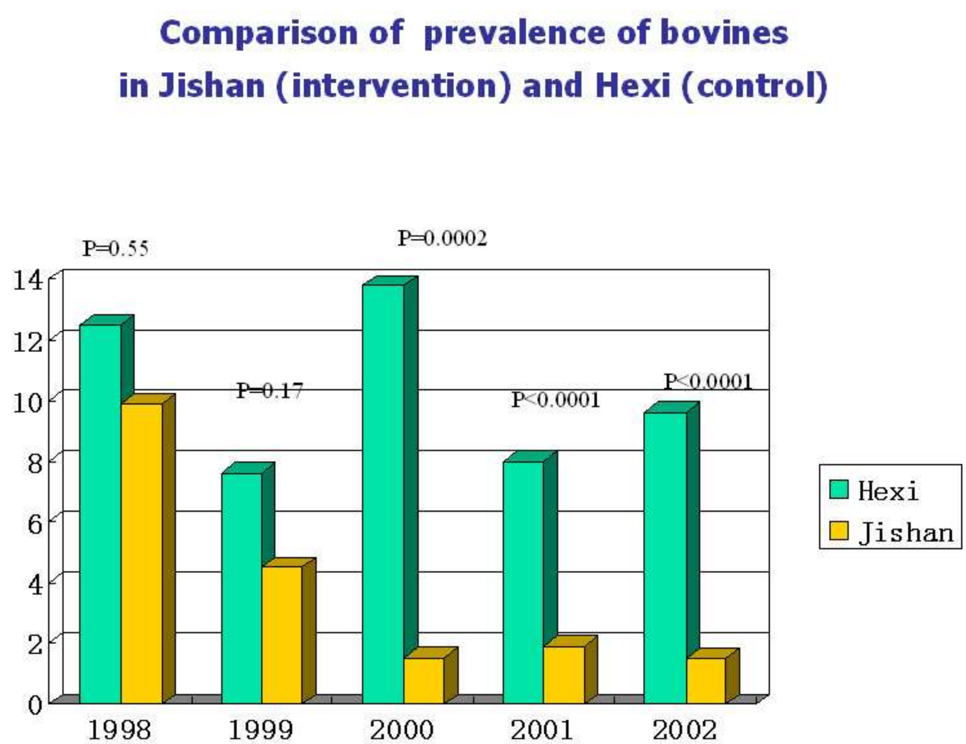

Figure 21 Bovine prevalence between 1998 and 2002

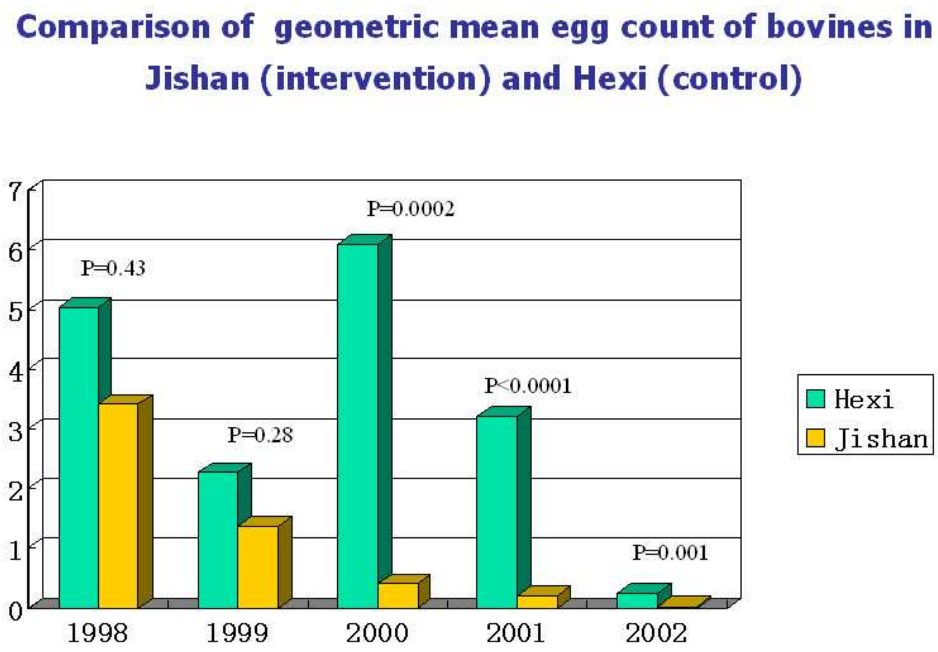

Figure 22 Geometric mean egg count of bovine between 1998 and 2002

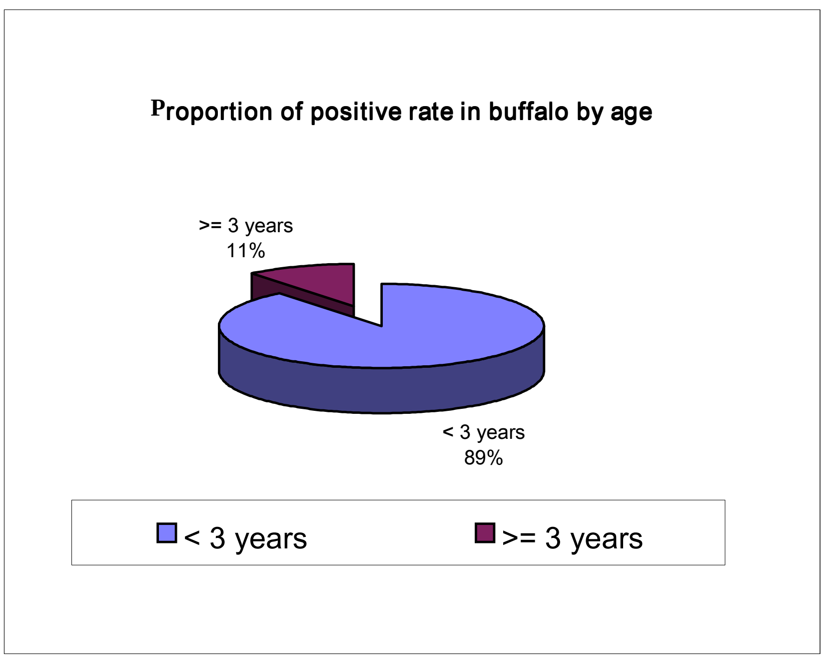

Figure 23 Infection prevalence in buffaloes by age

In 2001, both, the rate of re-infection and of new-infections were low (10% and 2.34%) in Jishan village, but still high (27% and 7.5%) in Hexi village.

It was also found that 89% of positive buffaloes were under 3 years old (Fig. 23). The infection rate of buffaloes under 3 years old was between 2% and 18%, while in buffaloes older than 3 years the infection rate was between 0 and 2.9% in the intervention and control groups, respectively.

It is appreciated that during the last two years of the study the infection sources for buffaloes were controlled, through successful monthly monitoring of the changes in the buffalo population and delivering chemotherapy accordingly.

There were significant differences in the prevalence of infections in snails between seasons due to seasonal fluctuations, water level changes and biological complexity. Through detailed analysis, it was shown that in two zones in the intervention village, snail infection rates reduced to zero.

9.5 Discussion and Conclusions

Schistosomiasis transmission is a complex process. Buffaloes are the main sources to contaminate the marshland due to large amount of faeces since eggs can survive longer time in faeces (Zhang et al, 1999). In this paper we determine the role of buffaloes in transmission of schistosomiasis. During the study, it was noted that in 2000, the prevalence in residents of the intervention village increased. We analyzed the reason and found frequent buffaloes exchanges in the year. From then onwards, the quality of the intervention in the two field sites was improved. Special attention was paid to the control of migrated and newly born buffaloes in Jishan village which might contaminate the marshlands. It was observed that there were 240 heads of cattle imported or newly born in 2001. This number is more than half of the whole bovine population in the village. Due to intensified control measures to bovine, the infection in humans was remarkably decreased from 14.0% in 2000 to 5.1% in 2001. When the strategy carried out one more year (2002), the prevalence remained stable at about 5% in the intervention village, while control village kept a high prevalence level (10%). No significant reduction of infection rate and intensity of infection both in humans and cattle have been observed in Hexi village. Although chemotherapy was carried out in infected villagers every year, the prevalence in the village remained high due to re-infection. This suggests that it is very difficult to achieve an effective control of the transmission only by applying chemotherapy treatment in high endemic areas like Hexi and Jishan. Detailed data on water contact (including snail-breeding water) over the study period confirms the effectiveness of bovine treatment at the level of 70%. Furthermore, over the 9 transmission seasons of the study, we noted increasing snail prevalence of infection in Hexi (by 17.3% per season) but a decrease in Jishan (by 15.1% per season). Through 5 years observations, it was also shown that 89% of the infected buffaloes were younger that 3 years old. This finding suggests that focus must be given in the treatment of young bovine in order to control schistosomiasis in the lake region.

Infection in humans is influenced by many factors, such as the frequency and intensity of exposure, environmental changes and water fluctuation patterns as well as activities of villagers. All the above factors may influence control effectiveness. It is very clear that the results in 2000 was not satisfactory. However, when all factors which could influence buffaloes contaminating the marshland were considered both, infection rates in residents and buffaloes were reduced in the intervention group. The objective of the study was to determine the role of buffaloes in *S. japonicum* transmission. The key to a successful intervention is to remove the infection source from buffalo and goats. This study showed also that a lot of time and manpower is needed to treat the buffaloes. The results of this study are very important in designing schistosomiasis control interventions in the lake region.

10 Compliance of Mass Chemotherapy on *Schistosomiasis japonica* in High Endemic Areas in the Poyang lake Region

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10.1 Abstract

Objectives: To estimate the magnitude of schistosomiasis *japonica* and amount of praziquantel needed for communities who live in highly endemic areas of Poyang lake region and to summarize the effects of 7 years of chemotherapy, including appraisal of the factors which influence people's compliance. **Methods**: Community based surveys were carried out and data were collected about demographic characteristics, awareness of schistosomiasis control and history of praziquantel in-take in a schistosomiasis endemic area. Parasitological data were also obtained by Kato-Katz examinations. **Results**: Among 1030 people interviewed, 48.9% reported contact with infected water. The majority of males reported fishing activities (64.9%), and the majority of females reported washing (78.3%). Annual chemotherapy coverage rates among 661 people between 1992 and 1997 were 63.8%, 67.2%, 69.4%, 62.6%, 57.2% and 75.5% respectively. Only 3.3% of the population were never treated, 9.7% received a single treatment, 10.2% of were treated twice, 16.2% received triple treatment, 15.2% were treated four times, 16.2% were treated five times and 29.1% were treated six times. It was found that stool-positive individuals were taken their medicine more often (79.7%) than the stool-negative individuals (73.9%), however this difference was not statistically significant ($P>0.05$). **Conclusion**: In the high endemic area, the study was carried out, 94.4% individuals accepted chemotherapy, but the effective chemotherapy coverage was about 60% each year and local people's infection rate was still 38%. The reason of refusing praziquantel was that the side-effects of the treatment influenced work ability, and that some adults (35.7%) thought that they were not infected. To achieve effective control in high endemic areas, it is necessary to adjust the strategy of schistosomiasis control to the targeted population groups, to increase the compliance of chemotherapy of local residents through health education and to select the most suitable time for chemotherapy in order to avoid the farming season. It is also important for health service support to increase the effective coverage.

Key words: Schistosomiasis, praziquantel, compliance

10.2 Introduction

The schistosomiasis control strategy in China is that of mass chemotherapy with a 95% coverage in high endemic areas (infection rate ≥15%) and selected chemotherapy in middle and low endemic area (infection rate <15%). After 5 years of control, infection rates of local people were reduced to 12.8% in Nanjishan Township, Xinjian County, Jiangxi Province which it is still high because it was proved difficult to achieve a 95% coverage rate. The compliance is an important factor in designing a control strategy (Guo et al, 1999). Praziquantel is regarded as a safe and effective medicine (Mao, 1990), but people don't like its taste and the fact that it has to be taken often, particularly if people think that they are not sick. This affects chemotherapy coverage. Neither high theoretical efficacy of disease control tools, nor diagnostic accuracy, nor good compliance, nor adequate coverage can lead on its own to the final goal of community effectiveness (Tanner et al, 1993). Some modeling of the cost-effectiveness of schistosomiasis control considered age-targeted treatment and varying frequencies of treatment and the interaction between drug price and drug efficacy (Guyatt, 1998). The purpose of this study is to analyse surveillance questionnaires of different population groups in a high schistosomiasis *japonica* endemic area, to compare compliance of people accepting praziquantel, to determine factors influencing mass chemotherapy, and to offer a scientific basis for control strategies in high endemic area.

10.3 Material and Methods:

Study area:

The study was carried out in Nanjishan Township which is located on an island in the Poyang Lake, in Xinjian County of Jiangxi Province. The island is isolated during the flooding season. In the three administrative villages and 10 natural villages of the county, there are 1441 families, and a population is 4782 people. 2374 of them are males. Local people are mostly farmers and fishermen. The highest record of schistosomiasis infection prevalence was 70%.

Data collection

1030 individuals between 6 and 60 years old were randomly selected in each village. In order to evaluate this county's infection situation, Kato-Katz stool examinations were carried out 3-times for each person. In addition, questionnaire were administered and the following information was collected:

- Demographic data (a person's occupation, age and sex)
- Knowledge of schistosomiasis control.
- Attitude and compliance to praziquantel treatment and stool examinations

Reviews surveys were conducted: to collect data on praziquantel treatment over 7 years, to analyses the chemotherapy coverage situation and perception of praziquantel treatment. Patients were also treated and patient records were kept.

Ten professionals from Xinjian County Station of Schistosomiasis Control were recruited and trained. The questionnaires in Nanjishan Township were filled by locally trained staff.

10.4 Results

The prevalence of schistosomiasis detected by stool examination was 38.1%. (251/651). The prevalence was 40.3% (151/375) in males, and 35.2% (100/284) in females. 1030 persons completed the questionnaires; there were 505 males and 525 females, 142 children between 7-14 years old, 836 persons between 15-60 years old.

Among those people identified with schistosomiasis infections, 48.9% belived that the cause was due to contaminated water, 13.3% thought they suffered from weakness, 9.7% thought it was diarrhoea. Among children (7-14 years old), 47.8% thought the cause was because of playing with water, 64.9% of males thought it was due to infections by fishing, 78.3% of females thought it was due to washing.

46.1% of local people thought praziquantel was not harmful, 53.9% thought it was harmful; 71.3% thought blood examination was not harmful, 11.3% thought it was harmful. 95.7% of children accepted the chemotherapy. This figure was 88.5% and 80.4% among the adults and the elder (over 50 years old), respectively.

Among the unwilling to receive chemotherapy, 41.2% complained about high costs, 21.6% complained about the taste. 85.7% of people wanted a blood examination before chemotherapy, 46.6% of people were afraid of needles and blood and 28.0% were afraid for no reason at all. 94.4% of people accepted treatment conditional that they were positive, and even 52.6% of people accepted treatment although they were negative to schistosomiasis infection. 81.7% of the people were actively treated because of the control project, 18.5% were passively treatment. 35.4% people experienced no side-effects after medicine-taking, which 15.9% had nausea and vomiting, 24.9% had headaches and 21.6% had abdominal pains.

The praziquantel coverage in the survey of 661 local people was 63.8% in 1992, 63.5% were males and 64.3% were females. In 1993, the coverage was 67.2% (69.6% were males and 64.0% were females). In 1994 the coverage was 69.4%, (71.7% were males and 66.4% were females). In 1995 the coverage was 62.6%, (68.0% were males and 55.6% were females). In 1996 the coverage was 57.2% (61.3% were males and 51.7% were females). Finally, in 1997 the coverage was 75.5% (82.7% were males and 66.8% were females), (Table 25).

In a random review of 659 patient record, 22 persons (3.3%) did not receive any chemotherapy during the 6 years, 64 persons (9.7%) had 1 times chemotherapy, 67 persons (10.2%) had 2 times chemotherapy, 107 persons (16.2%) had 3 times chemotherapy, 100 persons (15.2%) had 4 times chemotherapy, 107 persons (16.2%) had 5 times chemotherapy and 192 persons (29.1%) had 6 times chemotherapy (Table 26).

Table 25 Chemotherapy coverage from 1992 to 1997

Sex	Number	Coverage of chemotherapy					
		1992 (%)	1993 (%)	1994 (%)	1995 (%)	1996 (%)	1997 (%)
Male	375 (100)	238(63.5)	261(69.6)	269(71.7)	255(68.0)	230(61.3)	310(82.7)
Female	286 (100)	184(64.3)	183(64.0)	190(66.4)	159(55.6)	148(51.7)	191(66.8)
Total	661 (100)	422(63.8)	444(67.2)	459(69.4)	414(62.6)	368(57.2)	401(75.5)

Table 26 Relationship between the length of chemotherapy and stool examination by sex

	Total	Chemotherapy time						
		Un-treat (%)	Once (%)	Twice (%)	Three (%)	Four (%)	Five (%)	Six (%)
Male								
Positives	151	1 (0.7)	9 (6.0)	22 (14.6)	25 (16.6)	28 (18.5)	17 (11.3)	49 (32.5)
Negatives	224	4 (1.8)	10 (4.5)	29 (12.9)	35 (15.6)	35 (15.6)	35 (15.6)	76 (33.9)
Sub-total	375	5 (1.3)	19 (5.1)	51 (13.6)	60 (16.0)	63 (16.0)	52 (13.9)	125 (33.3)
Female								
Positives	100	4 (4.0)	18 (18.0)	3 (3.0)	18 (18.0)	14 (14.0)	17 (17.0)	26 (26.0)
Negatives	184	13 (7.1)	27 (14.7)	13 (7.1)	29 (15.8)	23 (12.5)	38 (20.7)	41 (22.3)
Sub-total	284	17 (6.0)	45 (15.8)	16 (5.6)	47 (16.5)	37 (13.0)	55 (19.4)	67 (23.6)
Total	659	22 (3.3)	64 (9.7)	67 (10.2)	107 (16.2)	100 (15.2)	107 (16.2)	192 (29.1)

10.5 Discussion and conclusion

In a high endemic area, local residents knew about schistosomiasis infection routes and modes, and that praziquantel is a drug to treat the disease. Most of them were willing to accept stool examinations and subsequent chemotherapy. In general, when they feel weak, they seek medical advise at a doctor or take drugs. When they have not any symptoms, they did not like to take drug. According to the strategy of the World Bank Loan Program of Schistosomiasis Control Project, 95% (6-60 years old) of the people had to be treated by chemotherapy once a year in high endemic areas. In fact, among people having chemotherapy over a 6 year period, 45.3% had more than 5 times chemotherapy, 60.5% had it more than 4 times, 76.7% had it more than 3 times, 86.9% had it more than 2 times. The percentage of acceptance of chemotherapy was more than 94.4%, but the chemotherapy coverage did not reach the requirement 95%. Some adults complained that chemotherapy is expensive, while a large population of children complained of its bitter taste. Some studies have shown that parents may be willing-to-pay for the treatment of their children but the actual amount that could be recovered and the ability of households to pay these amounts is uncertain (Guyatt, 2003).

In the analysis of the questionnaires, we also found that among non-medicine takers 1/3 of the adult did not think they were infected with schistosomiasis, which indicates that the symptoms were not severe enough. But people always want to keep some praziquantel for their children or to share the drug in case they experience symptoms in the future. Unlike *S. mansoni*, a proportion of these symptoms increased with increasing infection intensity of *S. mansoni* (Berhe et al, 1999). 2/3 of the adults had side-effect after praziquantel administration. The main symptoms were headaches (24.9%), abdominal pain (21.6%), nausea and vomiting (15%), which influenced people's working ability. Similar findings were reported after praziquantel treatment against *S. mansoni*, but most of the treatment related symptoms were mild. However, some of the symptoms were at times severe and could reduce drug compliance in primary health care based population chemotherapy (Berhe et al, 1999).

Mass chemotherapy intervention can stop the transmission of *S. haematobium* for at least one year and reduced the prevalence from 21% to 4.6%, for mansoni infections, the incidence remained very high (50%) and the prevalence was stable after one year follow-up (Saladin et al, 1983). In Egypt, treatment noncompliance was 30%, for which half had justifiable reasons. The others simple refused treatment many whom were nevertheless examined for infection. Mass chemotherapy was found to be a feasible and an effective method to reduce the prevalence and intensity of *S. haematobium* endemicity (Talaat and Miller, 1998). For successful schistosomiasis control programmes, there are three central features: 1) recognition of the public health significance of schistosomiasis; 2) political will and commitment to utilize local resources for control; and 3) readily available public health infrastructure for the delivery and maintenance of control interventions (Chitsulo et al, 2000; Engels et al, 2002). The suggestion for increasing control effectiveness is screening people by questionnaires to eliminate people without infection and focusing blood examinations to susceptible cases. Suitable chemotherapy duration will be selected in order to avoid the farming and fishing season to increase local people's compliance.

With repeated mass chemotherapy in high schistosomiasis endemic areas, the infection rates and intensity would be reduced over time, which is important for morbidity control. But the compliance could be reduced since carrying out mass chemotherapy on the same group of people for many years can increase their reluctance to be treated. In our study, the average chemotherapy coverage rate is

65.9% each year, the males being more compliant than the females, but there is no significant statistical difference (P>0.05). In total, 192 people (30%) have had 6 times the treatment in 6 years. The number of people undergoing chemotherapy in 1997 was higher than that compared to the previous years. The main reason was that the treatment was free in 1997 but not before. The stool-positive people tended to take their medicine more often (79.7%) than the stool-negative people (73.9%), but this difference was not statistically significant (P>0.05). A case study was carried out in a marshland area in Guichi County of Anhui Province and shore of the Quipu River whose water runs into the Yangtze River. The results showed that by 1 year selective mass chemotherapy, the prevalence of schistosomiasis reduced from 19.2 to 8.0%. After a 4-year chemotherapy campaign, the prevalence was reduced to 4.9%. However, after the selective mass chemotherapy was ceased, the prevalence of schistosomiasis arose quickly. When chemotherapy stopped for 2 years, the prevalence reached almost pre-intervention levels (13.6%) (Jiang et al, 2000). Chemotherapy has been an important element of schistosomiasis control. The study demonstrated that appropriate drug treatment lowers worm burden and decreases the intensity of the infection as well as prevalence. However chemotherapy alone can not eliminate the transmission, because zoonotic *S. japonicum* infection has a great impact on the epidemiology and control of the diseases.

in high schistosomiasis endemic area the chemotherapy coverage was around 60%. The cost of chemotherapy is an important factor which affects coverage.There are not clear differences in chemotherapy compliance between infected and non-infected individuals. Male chemotherapy coverage rates are higher than those of females. Male infection rates are also higher than those of females. For planning control strategies in high schistosomiasis areas, chemotherapy compliance can increase by health education (Hu et al, 2000a,b). Some results show that infections with *S. japonicum* can be controlled effectively among women, and especially by pupils, which are obedience to examination.

Chemotherapy is a very important measure in morbidity control. It is necessary to continue the activities on strengthening the control programme for morbidity control strategies in high endemic areas, and maintain and consolidate the achievements in medium endemic areas. In order to control effectively in high endemic area, it is necessary to increase the rate of local people’s treatment and the effective of chemotherapy. Except the health education and increasing chemotherapy compliance, it is important for health service support to increase the effective coverage, to adjust the strategy of mass chemotherapy to local conditions and to select the timing of the chemotherapy outside the farming season. It seems imperative to take full advantage of the contemporary international emphasis on the provision of clean water and sanitation as the fundamental basis for schistosomiasis control. Implementation of integrated water resource management would not only introduce an unprecedented potential for sustainable control, but it would also serve to sharply reduce the prevalence of a broad range of intestinal parasites. Importantly,, this strategy would mutually reinforce chemotherapy-based morbidity control (Utzinger et al, 2003).

It is clear that many factors influence the coverage and compliance of chemotherapy. In order to increase the coverage of chemotherapy and its compliance, we suggest 1) to treat persons who were identified by inquiry and proved positives instead of the mass chemotherapy (Jiang et al, 1999). Questionnaires are now available for promptly defining the magnitude of schistosomiasis in large areas, which will allow limited resources for morbidity control to be allocated optimally (Lengeler et al, 2002). The method will benefit the morbidity control and reduce some people who have not water contact history, 2) mass chemotherapy will be used with the natural village* as the unit instead of the administration village (Xu et al,1998). It will reduce the scale for mass chemotherapy, and avoid mass chemotherapy to be carried out in low prevalence natural villages, 3) the optimal time for chemotherapy should not be during the busy season of agriculture. In this way, it will not influence labor force due to some side effects. 4) health education can promote the compliance of chemotherapy in local residents and increase the coverage of chemotherapy, 5) health service support and local leader collaboration can exemplify problems linked to the compliance of users/providers and coverage.

* (A “natural” village is a settlement within an administrative unit called a village. An administrative village is often composed of many settlements, or “natural” village)

11 The role of passive chemotherapy in schistosomiasis control during maintenance and consolidation periods

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This article is a working paper

11.1 Abstract

Objective To explore the role of passive chemotherapy in schistosomiasis control and to set up cost-effective strategies during maintenance and consolidation periods of schistosomiasis control in China. **Methods**: Two high endemic villages (Fanhu and Yuanyang) were selected to carry out strategy A (passive chemotherapy plus health education) and strategy B (mass chemotherapy only) respectively and compare their cost-effectiveness. **Results**: In strategy A the rate of treated positive population is 96.15% and 97.06% in the two villages respectively, and in strategy B the rate is 100% and 100%. But the cost of strategy A is 49.04% (1998) and 54.60% (1999) lower than strategy B. **Conclusion**: Strategy A has some advantages such as low costs, effectiveness and acceptability for residents. It can be used as the strategy of schistosomiasis control during maintenance and consolidation periods. It plays an important role on morbidity control in high endemic areas. Meanwhile it is very easy to combine with the Primary Health Care network system.

Key words: Schistosomiasis control; passive chemotherapy; health education; active chemotherapy.

11.2 Introduction

There is a strong evidence from countries where the public health importance of schistosomiasis was recognized and schistosomiasis control implemented, that the WHO-recommended strategy for morbidity control is effective. Four national control programmes (Brazil, China, Egypt and the Philippines) can be cited where concerted control efforts together with economic development has decreased morbidity to very low levels (WHO, 1998). The World Bank Loan Project on Schistosomiasis Control in China (WBLP) suggested the strategy of mass chemotherapy once a year for the 6-60 years old in high endemic areas (infection rate ≥15%). Although the mass chemotherapy plays an important role in morbidity control, some side-effects have to be considered, such as compliance of residents after frequent drug taking, cost of treatment and potential for drug resistance (Hu et al, 2000a,b).

In this study, we assess “passive chemotherapy” as an alternative control strategy to the traditional mass chemotherapy. The study was carried out in two high endemic villages, named, Fanhu and Yuanyang, in Poyang lake during 1998-2000.

Two control strategies were implemented. One strategy was involved passive chemotherapy plus health education and the other strategy involved mass chemotherapy only. The two interventions are compared in terms of their efficacy, cost-effectiveness and their acceptability by the local population.

11.3 Materials and Methods

Field study

Two schistosomiasis endemic villages (Fanhu and Yuanyang) were selected in Poyang Lake Region, Jiangxi Province. The natural environment and social economic level in the two villages were similar. The prevalence of schistosomiasis were 27.51% and 24.79% in 1992, respectively. Mass chemotherapy was implemented in the 2 villages by WBLP. After implementation, the infection rate was reduced remarkably in both villages. Passive chemotherapy and health education was applied in Fanhu village. Yuanyang village was considered as a control group where mass chemotherapy was used. 423 and 362 individuals (6-60 years old) were included in the study from Fanhu and Yuanyang village, respectively. Individuals positive for schistosomiasis were identified by Kato-Katz examination.

Passive chemotherapy

The researchers visited villages with medical teams, and noticed the time and place of treatment of local people. The patients would meet the medical teams and be actively treated (Praziquantel 40mg/kg for adult, 60mg/kg dosage for children). They also received relevant health education prior to the treatment. Audio-video materials and person to person exchanges were used to communicate ways of infection, schistosomiasis harmfulness and importance of early stage treatment.

Mass chemotherapy

Following the criteria of WBLPSC, the local people among 6-60 years old are given chemotherapy without examination in high endemicity areas. The compliance was reduced because of frequent mass chemotherapy. In order to increase the chemotherapy coverage and disease control quality, medical teams distributed medicines to local people and persuaded them to receive the treatment. Compared with passive chemotherapy, this method is called “active chemotherapy”, that is, medical teams knock the door to treat resident house by house.

Cost

The costs of each control strategy was calculated taking into account the cost of medication, health education and salaries. The cost does not include medical team's transportation and some subsidies.

11.4 Result

Infection prevalence

In December 1998, the prevalence of infection was 12.2% (52/423) and 11.04% (40/362) in Fanhu and Yuanyang villages, respectively. A year later, the prevalence was dropped to 7.97% and 6.35% respectively (Table 27).

Table 27 Results of stool examination among populations in Fanhu and Yuanyang villages

Date examined	Village	No. survey	No. stool examined	No. of positive	Positive rate (%)
Dec. 1998	Fanhu	423	423	52	12.20
	Yuanyang	362	362	40	11.04
Dec. 1999	Fanhu	423	423	34	7.97
	Yuanyang	362	362	23	6.35

Chemotherapy coverage of the positive cases (determined by stool examination)

In February 1999, the treatment rate of stool-positive individuals was 96.15% (50/52) in Fanhu village and 100% (40/40) in Yuanyang village. The difference was not statistically significant ($P>0.05$). A year later, the treatment rate of the infected individuals was 97.06% (33/34) in Fanhu and 100% (23/23) in Yuanyang (Table 28).

Table 28 Coverage rate of chemotherapy in *Schistosoma japonicum* infected population in Fanhu and Yuanyang village

Date of chemotherapy	Village	No. survey	No. chemotherapy	No. chemotherapy stool-positives	Treatment rate in stool positives %
Feb. 1999	Fanhu	423	121	50	96.15
	Yuanyang	362	353	40	100
Feb. 2000	Fanhu	423	123	33	97.06
	Yuanyang	362	344	23	100

Cost-effectiveness of the two strategies

Transportation cost for researchers and medical teams as well the duty trip fees were not included in the cost estimation.

The average salary of the educators and the medical staff is RMB31.2Yuan/person/day. The health education programme in Fanhu was implemented for 3 personnel-workdays in February, 1999 and 2 personnel-workdays in February, 2000. giving rise to a cost of RMB93.6Yuan and RMB62.4 Yuan, respectively. The health material fees in the two villagers were RMB184.3 Yuan and RMB101.9 Yuan, respectively. Thus the total cost of salaries and educational materials was RMB277.9 Yuan and RMB164.3 Yuan, respectively.

The average medicament fee (including the side-effect treatment fee of RMB0.20 Yuan/person/time) was RMB4.7 Yuan/person/time. The chemotherapy treatment required 2 personnel-workdays in Fanhu village each year and 4 and 5 personnel-workdays in Yuanyang village in February 1999 and 2000, respectively. During both chemotherapy treatments, the cost in Fanhu was 49.04% and 54.60% lower than those of Yuanyang village, in 1999 and 2000, respectively. By the cost-effectiveness analysis, the treatment rate of the stool positive people in Fanhu and Yuanyang villages were similar. The 2 years cost of Fanhu village was noticeably lower than that of Yuanyang village (Table 29).

Table 29 The cost of schistosomiasis control in Fanhu and Yuanyang villages

Year	Village	Cost of chemotherapy			Cost of health education			Total cost
		Drugs	Wages	Total	Materials	Wages	Total	
1999	Fanhu	568.70	62.40	631.10	184.30	93.60	277.90	909.00
	Yuanyang	1659.10	124.80	1783.90	0	0	0	1783.90
2000	Fanhu	578.10	62.40	640.50	101.90	62.40	164.30	804.80
	Yuanyang	1616.80	156.00	1772.80	0	0	0	1772.80

11.5 Discussion and Conclusions

As we know schistosomiasis control is very hard and long-term work. A lot of experiences show morbidity control is a very effective method in high endemic areas, but it also has some problems with compliance, costs and resistance (Guo et al, 1999). Mass chemotherapy carried out many years in some high risk areas. Many studies explored several strategies of control schistosomiasis. There is a need to develop low cost interventions and follow-up procedures to prevent resurgences of transmission after successful control efforts, when the infection is no longer of public health importance (Bergquist, 2001). Models of the development of early- and late-stage morbidity could substantially contribute to more cost-effective strategies of passive and active chemotherapy. Modelling can also contribute to a better understanding and improvement of results of ongoing control efforts, in particular the impact of repeated chemotherapy (Gryseels, 1996).

Experts suggest that the national health department should be more aggressive in dealing with the disease in terms of ensuring implementation and of continuously searching for better and improved methods of control (Leonardo et al, 2002). In Senegal, four years after the start of the intervention project, patients presenting schistosomiasis related symptoms could generally expect proper diagnosis and treatment at all levels of the health care system, either at the initial health care facility visited or after referral. However, a further reduction of the total costs of treatment is still possible by a better implementation of symptom-based treatment and further reduction of the costs of PZQ (Ven der Werf et al, 2002). In sub-Saharan Africa, the questionnaires are now available for promptly defining the magnitude of schistosomiasis in a large areas, which will allow limited resources for morbidity control to be allocated optimally (Lengeler et al, 2002).

In the Poyang lake region, the World Bank Loan Project on schistosomiasis control was carried out for 10 yeas (1992-2002). Fanhu and Yuanyang villages had high schistosomiasis endemicity and after mass chemotherapy was implemented by WBLP, the schistosomiasis prevalence was remarkably reduced. The study reported here was implemented during 1998-2000. The results indicate that there was no difference in disease control between the two villages through the different strategies employed. The total cost of passive chemotherapy with health education during the whole of study period in Fanhu was much lower than the cost of mass chemotherapy in Yuanyang. Local people accepted more easily the strategy of passive chemotherapy and health education. From a point a view of cost-effectiveness and field implementation, the passive chemotherapy plus health education is superior to mass chemotherapy. This strategy is recommended for the strategy of schistosomiasis control during maintenance and consolidation periods.

The key of success in the implementation of passive chemotherapy is schistosomiasis health education. The objective of this education is the awareness so that people who have contact with infected water or have symptoms seek for treatment actively. In Africa, the use of self-reported schistosomiasis or self-reported blood in urine was met with success. It should be continually supported as a simple, cheap and cost-effective tool for identifying schools at high-risk of schistosomiasis (Ansell and Guyatt, 2002). “Blood in stool” is the most reliable reported symptom for rapid and low-cost identification of communities that are at high risk of *S. mansoni* infection s in the Ivory Coast (Utzinger et al, 1998). Using the questionnaire to screen school children is a rapid, low-cost method (Lengeler et al, 1991a,b). Before treatment, the high transmission area, infection mode, schistosomiasis harmfulness and importance of early stage treatment are taught to local people by audio-video materials and personal communication. After education, people understand how schistosomiasis infections is transmitted by contact with infected water and the importance of prompt treatment. The treatment rate of infected people will increase following the health education, as well as, treatment won’t be distributed to people who do not need it.

The cost of mass chemotherapy is higher than that of passive chemotherapy plus health education. The reasons are: a) the additional medical costs involved in treating many people even though they are not infected; b) the World Bank Loan Project required a mass chemotherapy coverage of more than 80%. Medical team went to each village and delivered medicines house by house. With repeated mass chemotherapy in high schistosomiasis endemic areas, the infection rates and intensity would be reduced over that period of time, which is considered useful. But the compliance could be also reduced since carrying out mass chemotherapy on the same group of people for many years can increase their reluctance to be treated (Guo et al, 1999). Compared with mass chemotherapy, the cost and personnel workdays for passive chemotherapy plus health education is lower.

Primary Health Care is a basic health care unit in countryside, and it would be desirable to combine its efforts with those of the anti-schistosomiasis station at county level. Most of the data collected by the community or its segments allow immediate feedback and form the basis for new or adopted strategies (Tanner and Degremont, 1986). Both staff from anti-schistosomiasis stations at county level and health workers at village level carrying out passive chemotherapy can effectively control schistosomiasis morbidity in particular, during the maintenance and consolidation period. It is recommended as a long-term strategy to combine Primary Health Care in grass root with the efforts of the anti-schistosomiasis station.

It seems imperative to take full advantage of the contemporary international emphasis on the provision of clean water and sanitation as the fundamental basis for schistosomiasis control. Implementation of integrated water resource management would not only introduce an unprecedented potential for sustainable control, but it would also serve to sharply reduce the prevalence of a broad range of intestinal parasites. Importantly, this strategy would mutually reinforce chemotherapy-based morbidity control (Utzinger et al, 2003). Many scientists thought and explored the strategy of schistosomiasis control during the maintenance and consolidation period. It was suggested: 1) to treat persons who were identified by inquiry and proved the cases instead of the mass chemotherapy (Jiang et al, 1999), Questionnaires are now available for promptly determine the magnitude of schistosomiasis morbidity in large areas, which will allow limited resources for morbidity control to be allocated optimally (Lengeler et al, 2002); 2) mass chemotherapy will be used with the natural village as the unit instead of the administration village (Xu et al, 1998). This approach will reduce the scale of mass chemotherapy, and avoid implementation of this strategy in the low prevalence natural villages; 3) the optimal time for chemotherapy should not be during the busy season of agriculture. In this way, it will not influence labor force due to some side effects; 4) health education can promote the compliance of chemotherapy in local residents and increase the coverage of chemotherapy; 5) health service support and local leader collaboration are presented to exemplify problems linked to the compliance of users/providers and coverage. A successful schistosomiasis control program should have three central features: 1) recognition of the public health significance of schistosomiasis; 2) political will and commitment to utilize local resources for control; and 3) readily available public health infrastructure for the delivery and maintenance of control interventions (Chitsulo et al, 2000; Engels et al, 2002).

12 New Approaches and Strategies for Schistosomiasis Control in China

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This article is a working paper

12.1 Abstract

Schistosomiasis control has been carried out for nearly 50 years in China. During these years, some new chemicals and new techniques have influenced the strategies for schistosomiasis control. Before praziquantel, the strategy was mainly large-scale snail control and elimination carried out in the course of, and in combination with, agronomical practices and water concervation measures, supplemented with chemical mollusciciding. Since the 1980's, praziquantel has been proven to be safe and effective drug. In addition, immuno-diagnosis techniques have come out in the 1970's. The strategy of schistosomiasis control changed. Large scale case screening and treatment both to humans and domestic animals have been promoted and became a mainstream in schistosomiasis control. Meanwhile socio-medical, health economics and environmental epidemiology have developed rapidly, enriching the strategy of schistosomiasis. It now focuses on the individual protection and health education, supplemented with safe water supply and proper disposal of human excretion. Recently, new prevention drugs such as artemether or artesunate for example will transform traditional treatment into newer preventive approaches as combinations with praziquantel and artemisinin derivatives explore new chemotherapies. In addition, GIS/RS application will play an important role in schistosomiasis surveillance and control, bringing new, integrated, multi- knowledge strategies in China.

12.2 Introduction

Since the founding of the People's Republic of China, under the leadership and profound concern of the Chinese Communist Party and central government, great achievements have been made in schistosomiasis control which have attracted worldwide attention. According to the investigations of the early phase of the control programs, schistosomiasis was endemic in 370 counties of 10 provinces of Hunan, Hubei, Jiangxi, Anhui, Jiangshu, Zhengjiang, Fujian, Guangdong, Yunnan, Sichuan, the municipality of Shanghai and the autonomous region of Guangxi. A total of 11.6 million persons were estimated to be infected and the population at risk of infection was greater than 100 million. The total areas of Oncomelamia snail habitats were about 14.3 billion m2 (Qian, 1986).

At present, after more than 40 years' of control, schistosomiasis has been eliminated in 236 counties (cities) in 5 provinces, whereas in 52 counties (cities) the criteria of transmission control have been reached. The total number of infected persons was about 820,000 by the year 2002 and that of estimated infected bovines, 31,547 (Chen et al, 2002). At the beginning, control programs put emphasis on snail elimination. Later chemotherapy has been the key approach, supplemented with snail elimination and health education in areas with high transmission potentials.

12.3 Control strategies and chemicals used for the treatment of schistosomiasis before 1980

Chemotherapeutic agents

The first treatment agent for schistosomiasis is tartar emetic. In 1918, Christopherson, reported on the drug which had been used for the treatment of *Schistosoma haematobium* infection for half a century. It was also the main drug for treating schistosomiasis *japonica* and schistosomiasis *mansoni*. The drugs had the characteristics of long treatment course, higher toxicity, lower therapeutic effect and intravenous administration.

Since 1955, studies on chemical synthesis, chinese herbs, pharmaclogy, drug preparation, biochemistry and clinical aspects of anti-schistosomiasis drug have been widely carried out. Between 1960 and 1978, a number of chemotherapeutic agents were discovered, such as furapromide, sodium antimony subgallate (Sb-273), niridayole, amoscanate etc. These chemicals had played a role as major drugs in the treatment of schistosomiasis in China (Mao, 1990).

The strategies for schistosomiasis control

According to the geographical patterns and epidemiological characteristics, endemic areas for schistosomiasis in our country have been divided into three types: 1) plain regions with waterway networks, 2) swamp and lake regions and 3) hilly and mountainous regions. According to the different endemic characteristics and relevant factors in different regions, control strategies have been adjusted accordingly. As a whole, the guidelines were to put prevention first and adopt comprehensive approaches according to local situation. (a) Large-scale snail control and elimination have mainly been carried out, and in combination with, agricultural and water conservancy processes, supplemented with chemical molluscicיding. (b) Large-scale case screening and treatment both to humans and domestic animals; (c) Individual protection and health education, supplemented with safe water supply and proper disposal of human excretion

The indices of examination

The main technical indices of transmission control for schistosomiasis are:(a) The prevalence rates by fecal examination in residents or domestic animals of less than 1%. (b) A reduction of more than 98% of snail habitats.

The main indices of schistosomiasis elimination are: (a) no new infection should be found either in man or in domestic animals for five successive years, (b) the prevalence rates by faecal examination in residents and domestic animals should be less than 0.2% and (c) no *Oncomelania* snails should be found after careful surveys for at least one year (Booklet, 1990).

Up until 2002, among 418 counties (according to current jurisdiction) previously endemic for schistosomiasis, the transmission had been interrupted in 247 counties. In 63 counties, the transmission had been under control, whereas in 108 counties, the disease was still endemic. The total number of infected persons was 820,000 and 90 million persons were at risk from the infection. The areas covered by snail habitats were 3.436 billion m2 in 2002 (Chen et al, 2002).

12.4 Influence of the use of praziquantel treatment on schistosomiasis control

The endemic situation of schistosomiasis

The two types of endemic areas, i.e., lake and mountainous regions, are challenging for schistosomiasis control.

Use of new chemicals

In 1977, praziquantel was synthesized in China. Both animal experiments and clinical studies have shown that the drug possessed the characteristics of low toxicity, high efficacy, short treatment course and easy administration. It can be widely used for treatment of acute, chronic, advanced schistosomiasis and for patients suffering complications with other diseases. It was a breakthrough in chemotherapy for schistosomiasis. The drug began to be widely used for treatment since 1980 after a few years clinical testing. It has been proven that praziquantel is safe and efficacious and thus can be used on large scale control programs (Mao and Shao, 1982).

Studies on control strategies

Since the 1980s, studies on schistosomiasis control strategies mainly by chemotherapy supplemented with snail elimination were carried out in areas with high transmission potential. Chinese scientists have done a lot of studies on field control strategies (Guo et al, 1999). Through those studies, a sound basis for schistosomiasis control mainly via chemotherapy since late 1980s has been set up.

Four strategies have been used for control (Yuan et al, 1990).:

- Elimination of the sources of infection plus limited snails elimination in areas with high transmission potential;
- Large areas snail elimination plus elimination of the sources of infection;
- High coverage chemotherapy to eliminate infection sources;
- Snail elimination in high transmission areas ;

As a result of carrying out the four control strategies, prevalence and intensity of infection were lowered. However the transmission of schistosomiasis can hardly be interrupted.

During the period of the “seventh five-year plan” period, Yuan et al (1990) conducted a research on the epidemiological factors influencing schistosomiasis transmission for four consecutive years in the Dongting and Poyang lake area. The researchers reported the peculiarity of the islet forming an endemic area, and a close relationship between the distance to the lake and the infection risk. The density of infected snails was used as an index in defining areas with high transmission potential. Yuan et al (1990) suggested also that for reaching the target of disease and infection control, large scale, synchronous chemotherapy both to man and domestic animals should be conducted (Yuan et al, 1990).

During the period of the “seventh five-year plan” and the “eighth five-year plan”, Zheng et al. (1996) studied control strategies for schistosomiasis in mountainous area. He suggested health education, snail and cercariae elimination in special environment, according to local situation, together with chemotherapy applied to both man and domestic animals. Field practice showed that these strategies were successful and also acceptable economically in the poor mountainous area.

12.5 Influence of health economics on control methods

In the early 1990s, domestic scientists analyzed theories of health economics on different control strategies and explored control approaches in different areas using cost-benefit analysis (Zheng et al, 1996).

Up until now, the World Bank loan project for schistosomiasis control is the biggest of the loan project to public health in China. The objective of the project was to reduce morbidity, using mass chemotherapy in areas with high endemicity, and selective chemotherapy in areas with medium and low endemicity. After the first three years of WBLP, the analysis on cost and effectiveness showed that when the infection rate was higher than 44%, the cost of mass chemotherapy was lower than that of selective chemotherapy. When the infection rate was lower than 44%, the cost of selective chemotherapy was lower than that of mass chemotherapy (Guo et al, 1998).

In the lake region, cost-effectiveness analysis between two control strategies, i.e., snails elimination combined with chemotherapy and chemotherapy alone in Jiangxi province showed that the required cost of chemotherapy alone was by 1% lower than that of the combined strategies of snail elimination and chemotherapy. The amount of cost increase in the combined strategies was lower in shorter than in longer-term (Yu et al, 1997a).

A study in Hubei showed that the cost of the combined strategy was 9.25 times as high as that of the chemotherapy alone, although the prevalence of schistosomiasis infection in humans and farm cattle was lower by around 70% (Yu et al, 1997). Studies on cost and effectiveness using selected and mass chemotherapy in Anhui province, showed that in higher endemic areas (prevalence greater than 12%) mass chemotherapy is suitable, whereas in areas with prevalence below 8%, selective chemotherapy is the method of choice (Shao et al, 1997).

The results of some other related studies also showed that (a) in the high endemic areas of the lake region, chemotherapy should be implemented at the level of the natural instead of administrative village because great differences in prevalence was found among natural villages as village inhabitants living at different distances from marshlands have different exposure to infested water. In addition, the cost of mass chemotherapy is significantly higher when this control strategy is applied at the level of the administrative rather than the natural village (Xu et al, 1998); (b) In areas with high endemicity, the results of clue chemotherapy consisting of treatment to those with contact with infected water and/or symptoms of infection showed a sensitivity of 95.5% and specificity of 52%. The mean cost of clue chemotherapy per person was 17% lower than that of mass chemotherapy (Jiang et al, 1999); (c) In heavily endemic areas, after mass chemotherapy and a decrease of prevalence rate of schistosomiasis by 73.1% was reached, selective chemotherapy strategy should be adopted in the second year (Lin et al, 1997).

12.6 Influence of health education and social medicine to control strategies

The new strategies put forward by WHO emphasize the effects of health education. An investigation on the compliance to chemotherapy among inhabitants showed that the willingness to accept chemotherapy was as high as 94.4%, and that 25.6% of the inhabitants had had praziquantel more than five times. This coverage was relatively low. 1/3 was unwilling to accept chemotherapy because they thought they were not sick. The other 2/3 considered that the drug had side effects (Guo et al, 1999). The compliance rate of chemotherapy can increase after health education. Studies on improvement of compliance among inhabitants to chemotherapy by health education showed that through education, compliance to chemotherapy went up from 50.0% to 90.6% (Lin et al, 1999).

After rural economic system reforms, the ways of production and people's habits in mountainous areas have been changed. Family clustering of the infection has made extended chemotherapy taking family as a unit comparatively easier (Zheng et al, 1989). In marshlands and river beaches, family clustering is now seen. The factors influencing the infection risk are the distance from snail habitats, the educational status of family heads and hygienic conditions (Huang et al, 1999).

Surveys from Yunnan revealed a significant relationship between prevalence in man and domestic animals and the development of animal husbandry (Zheng et al, 1994).

12.7 Artemisinin derivatives and combinations

The antischistosomal activities of artemisinin, artemether, and artesunate were discovered in the early 1980s, with the initial experiments on *S. japonicum* (Le et al, 1983; Mandour et al, 1990). More recent studies confirmed that artemether and dihydroartemisinin also have antischistosomal properties (Abdel and Badawy, 2000; Xiao et al, 1992). Laboratory experiments conducted so far in different animal models found that artemether is an active agent against the three major human schistosome parasites (Utzinger et al, 2001a,b; Xiao et al, 2002). Very similar stage-specific susceptibilities have also been reported for *S. japonicum* (Xiao et al, 1995). In contrast to praziquantel and oxamniquine, artemether exhibits the highest level of activity against 1- to 3-week-old liver stages, while the invasive stages and the adult worms are less susceptible. Adult female worms are somewhat more susceptible to artemether than male worms (Utzinger et al, 2001a,b), which is the opposite of the activity of oxamniquine. To date, clinical testing of artemether for the prevention of schistosomiasis included 2,670 people who received oral artemether at a dose of 6 mg/kg once every 2 to 4 weeks for periods of up to 6 months. Artemether was safe, showed no or only a few but transient side-effects, and was efficacious in reducing the incidence and intensity of infection (N'Goran et al, 2003; Utzinger et al, 2000c; Xiao et al, 2000).

Schistosomiasis chemotherapy primarily relies on praziquantel, but the present arsenal also includes oxamniquine and artemisinin derivatives. Some evidence suggests that combinations of praziquantel and artemether are more promising. Both drugs display broad-spectrum antischistosomal activities and act against different parasite stages; hence, the combination covers the entire parasite spectrum in its vertebrate host. Laboratory studies have clearly established a beneficial effect of combining praziquantel with artemether, since worm burden reductions were enhanced. The first results from clinical trials are encouraging, but there is a great need to carry out additional randomized controlled trials in different epidemiological settings. These findings are also likely to be of considerable importance for antischistosomal drug development. Since the 1990's, two chemicals, artemether and artesunate have been used in endemic provinces for the prevention of schistosome japonicum for more than 100,000 persons with success in China (Xiao et al, 2000).

During the flood season, after oral artemether was given to the people fighting against floods in schistosomiasis endemic area of Poyang Lake, it was shown that oral artemether has a promising effect on controlling acute schistosomiasis and reducing the infection rate (Song et al, 1998). Artesunate as well was found to be a safe, and highly efficient drug during the flooding of the Yangtze River in 1998. It was taken by 90,000 soldiers and cadres when fighting the floods (Yuan et al, 2000).

12.8 Exploring new control strategies using GIS/RS

Geographic information systems (GIS), global positioning systems (GPS), remote sensing, and spatial statistics are tools to analyze and integrate the spatial component in epidemiology of vector-borne disease into research, surveillance, and control programs based on a landscape ecology approach (Kitron, 1998). In general, this landscape approach could be applied to other vector-borne diseases in areas where 1) the landscape elements which are critical to vector survival are known and 2) these elements can be detected by remote sensing (Beck et al, 1994).

Climates and topography effectively restrict vector-borne infections to certain geographical areas, a clear illustration of how strongly the spatial distributions of these diseases rely on environmental factors. This is hardly a new revelation, but just a few years back, without the support of computer-assisted collection and handling of data, we were far less able to grasp the full picture. Fortunately climate data collection by Remote Sensing (RS) by earth-observing satellites, a technology particularly well suited to pinpoint constraining endemic factors, has not only become affordable but also reached a high degree of sophistication. Meanwhile, geographical information systems (GIS) and global positioning systems (GPS) permit spatial information of great accuracy as well as digitalization of collected data on the spot enabling visualization of the data in relation to physical maps and facilitating comparisons of the results of longitudinal investigations. Adoption of these technologies at the national level promotes intersectoral collaboration and promises improved planning and management in the control of endemic diseases (Bergquist, 2001a,b).

In China, the distribution of schistosomiasis risk is closely related to climate, elevation, soil quality and water composition. In the past, it was suggested that average yearly temperatures of 14^{o}C, and average temperatures of 0 ^{o}C in January are limiting factors for schistosomiasis propagation. However, in six out of 370 endemic counties the average temperature was lower than 14 ^{o}C（10.9 ^{o}C -13.9 ^{o}C）. As a result some experts considered that these limiting factors should be changed to average temperatures ≥10^{o}C and cumulative temperatures of 4000^{o}C. In mountainous areas, the prevalence of schistosomiasis decreased as well with altitude (Zheng et al, 1996). In the lake region, the snail distribution is related to elevation, water levels and vegetation (Luo, 1994).

As schistosomiasis prevalence is closely related to the geographical environment, using GIS techniques to determine the risk of infection has become popular (Zhou et al, 1998). The use of meteological and of remote sensing data have potentially practical value to predict the areas and intensity of infection (Zhou et al, 1998). Scientists have been already carrying out GIS techniques to predict the infection prevalence, to study the snail dispersion after floods as well as the impact of flooding on transmission (Guo et al, 2000).

Kristensen et al (2001) showed that data on the snail distribution corresponds with schistosomiasis prevalence data in relation to a forecast model based on NDVI and T(max) data derived from the Advanced Very High Resolution Radiometer (AVHRR) on board the National Oceanic and Atmospheric Administration satellite series. Using TM images, we can study the area where water and land shift during flood and dry seasons. The vegetation is a key factor for the snails survival. 94.3% of the snail habitats are distributed among areas whose NDVI values exceed 110. Vegetation and soil moisture cannot be measured directly by TM, however, the use of the Tasseled Cap model can enhance interpretation, by evaluating the wetness of the marshland and separating snail habitats from agriculture areas that are more wet or dry than the snail habitats (Guo et al, 2002).

13 A Baseline Study of the Importance of Bovines for Human *Schistosoma japonicum* Infections Around Poyang Lake, China: Villages Studied and Snail Sampling Strategy

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13.1 Abstract

An epidemiologic survey among four administrative villages around Poyang Lake, in Jiangxi Province, China (two experimental and two controls) is being conducted to determine if bovine infections are responsible for the persistence of human schistosomiasis transmission on Yangtze River marshlands. A previously published paper presented the experimental design and baseline data for humans and bovines. This paper presents basic data for the four villages using remote sensing, and baseline data for snails that includes geographic information systems and remote sensing technology to classify the areas of bovine grazing ranges and habitats suitable for snails. A new method for sampling *Oncomelania* snails in China is used to determine the distribution, density, and infection rates of snails throughout the grazing ranges from season to season over a four-year period. Hypothetically, treating bovines should reduce infection rates in snails to below the critical number necessary to maintain infections in man and bovines.

13.2 Introduction

The National Institutes of Health (United States) have funded a Tropical Medical Research Center (Institute of Parasitic Diseases, Chinese Academy of Preventive Medicine, Shanghai) epidemiological study to assess the importance of buffalo and cattle for maintaining optimal transmission sites in which human inhabitants become infected with *Schistosoma japonicum*. The hypothesis being tested is that buffalo and cattle grazing on the marshlands of Poyang Lake are responsible for 85% or more of the human infections in and around Poyang Lake (Davis et al, 1999). This hypothesis is derived from observations that most schistosome eggs deposited on marshland areas originate from bovines. It is also based on the average number of eggs excreted by infected bovines, combined with their typical frequency within herds and the average herd size, and the propensity of these animals to contaminate the environment with voluminous excreta. Other mammals are not relevant to transmission on Poyang Lake marshlands. Pigs are confined to pens; there are no clogs. Rodents are not a factor (from surveys of the Provincial Institute of Parasitic Diseases).

To test this hypothesis, four administrative villages were chosen of which two were experimental (Jishan and Dahuang) and two were controls (Xinhua and Hexi) (an administrative village may have two or more natural villages). Details of the protocol and why these particular villages were chosen have been reported in a paper that focuses on the human and bovine aspects of the study (Guo et al, 2001). It provides information on the primary design that involved treating with praziquantel, at the onset of the study, all the inhabitants in all four villages and all the buffalo and cattle in two villages (the experimental villages). Prior to treatment, the 'prevalence of infections in humans, buffalo and cattle, and snails was established. Following treatment, rates of reinfection in people of all villages, and in buffalo and cattle in the experimental villages were being assessed, as well as the ongoing prevalence of infection in buffalo and cattle in the control villages.

If the hypothesis is correct, the primary target for human parasite control involves the cycling of *S. japonicum* between buffalo and cattle throughout their grazing ranges and the snail intermediate host, *Oncomelania* hupensis hupensis, which is distributed throughout the grazing range. If the number of infections in buffalo and cattle fall to zero, snail infections should also decrease, perhaps far enough to interrupt the life cycle of the parasite.

This paper supplements the previous report (Guo et al., 2001) by focusing on a description of the villages, and providing the snail sampling procedures used to assess the distribution and abundance of snails (infected and non-infected) throughout the buffalo and cattle grazing range, and the baseline snail data. The descriptions are aided by remote sensing (RS) images and geographic information system (GIS) databases to assess the areas of the grazing territory and classify areas suitable for snails. The snail sampling procedure used is new and replaces the Chinese traditional method. The identification of "hot spots" where optical transmission sites are obtained, the primary sites where humans and buffalo and cattle become infected, is discussed.

13.3 Background

Poyang Lake, the largest lake in China (area = 4,647 km2) is one of the major endemic sites for schistosomiasis in China. Its environment is unique. High dikes surround the lake and permanent islands. All human habitation is behind the dikes, either outside the lake or on high ground in the lake. The largest river in Jiangxi Province, the Gang Jiang (jiang =river) runs through the lake and empties into the

Yangtze River through a narrow passage. During the annual monsoon and flooding of the Yangtze River, the lake fills up much like a bathtub, covering all the lowland marshlands and rising up against the constraining walls of the dikes. During flood season and high water, no persons venture out into the .lake except fishermen. All buffalo and cattle are removed to behind the dikes.

The flooding season runs from May-June to October- November. At the end of the rainy season, the lake loses as much as 90% of its water. As the water subsides, vast flat islands of grass-covered marshlands emerge, habitat suitable for cattle grazing and *Oncomelania* snails. Water ,buffalo are driven into the lake to forage on grasses even before the grasslands emerge. All infections occur within the lake basin. There are no snails behind the dikes (outside the dikes) and only people venturing out into the lake basin become infected. These include fishermen, cowboys who tend the cattle, and villagers who harvest grasses used for fuel for cooking (there are few trees, villages have no or limited electricity, and fossil fuels are prohibitive in cast or availability), wash clothes, and use the lake for recreational activities (swimming). The vast grasslands of Poyang Lake are difficult to reach and traverse. Reaching different locations requires use of small boats and buffalo carts.

The four administrative villages in the study have populations of 1,500-2,000 persons each. There is one water buffalo or cow per every 10 persons; thus, 150-200 cattle per village throughout the marshlands. In this study, the number ranged tram 1.9 to 12.3 bovines/person (Table 30). To put this in perspective, there are 1,125 endemic villages around Poyang Lake with a population of 1,750,000 persons. The average infection rate is 5.9%. The average rate in hyperendemic villages is 15.2% for residents and 12.9% for cattle. There are 615 units of snail breeding sites covering 80,000 hectares (data supplied by the Jiangxi Institute of Parasitic Diseases).

13.4 Methods

Time framework for the epidemiological trial and environmental considerations

The baseline collections of data were carried out in late October and November of 1998 (post-flood collection), and early May of 1999 (pre-flood collection). Collections from the two seasons were necessary for baseline data to assess the effects of winter on the populations (spring collection) and the effects of flooding on the populations (fall collection). The chance occurrence of the great Yangtze River flood of 1998, the worst in 40-50 years, had a serious impact on the study. It began as an early spring flood that was to devastate southern China. In our epidemiological control village of Xinhua, one section of grazing land (zone I), known to have an abundant snail population, was swept clear of snails; only four living snails were found there in the fall of 1998 or the spring of 1999. This grazing land has the lowest elevation of all the study sites. The floods came early and covered this land before the other areas; this area was the last to be uncovered after the waters receded. Temperatures were unseasonably cold in the spring. This, coupled with the high level of water, affected snail reproduction. The factors of temperature, timing, and duration of rainfall and flooding bad a negative impact on snail survival and reproduction. Heightened water levels increased the current sweeping over this lowland grazing land at the edge of the Gang River.

Table 30 Statistics and coordinates of the four villages, and coordinates for the squares sampled in each village

Statistics and coordinates for the four villages, and coordinates for the squares sampled in each village

	Control		Experimental	
	Hexi	Xinhua	Jishan	Dahuang
Coordinates				
Latitude	29°12′45″	29°17′35″	29°12′34″	29°13′08″
Longitude	116°02′28″	115°59′38″	116°04′39″	116°17′15″
Number of natural villages	6	19	4	12
Number of people	1,043	2,004	1,280	2,073
Number of buffalo	364	168	665	0
Number of cattle	0	0	0	168
Area of grazing range (km^2)				
Total	3.69	1.18	12.1	0.35
Houshan	2.06			
Shamo	1.63			
Area of hot spots (m^2)	A = > 50,000 E = > 60,000	E = 10,000	A = 50,000 E = > 10,000 G = 40,000	B = 10,000 C = 10,000 D = 10,000
Site coordinates				
A	29°11′46″ 116°03′17″	29°17′20″ 115°59′47″	29°12′47″ 116°04′06″	29°13′08″ 116°17′15″
B	29°11′53″ 116°03′02″	29°17′24″ 116°00′07″	29°12′34″ 116°03′24″	29°12′55″ 116°17′18″
C	29°12′40″ 116°02′35″	29°18′05″ 116°00′39″	29°12′25″ 116°03′44″	A′29°12′28″ 116°17′51″
D	29°12′35″ 116°02′24″	29°17′51″ 116°00′25″	29°12′34″ 116°04′39″	B′29°12′38″ 116°17′39″
E	29°12′03″ 116°02′28″	29°17′35″ 115°59′38″	29°12′43″ 116°02′06″	
F	29°12′17″ 116°02′04″		29°13′20″ 116°01′34″	
G	29°11′55″ 116°01′59″		29°12′33″ 116°04′19″	
	Figures 1 and 2	Figure 3	Figures 1 and 2	Figures 4 and 5

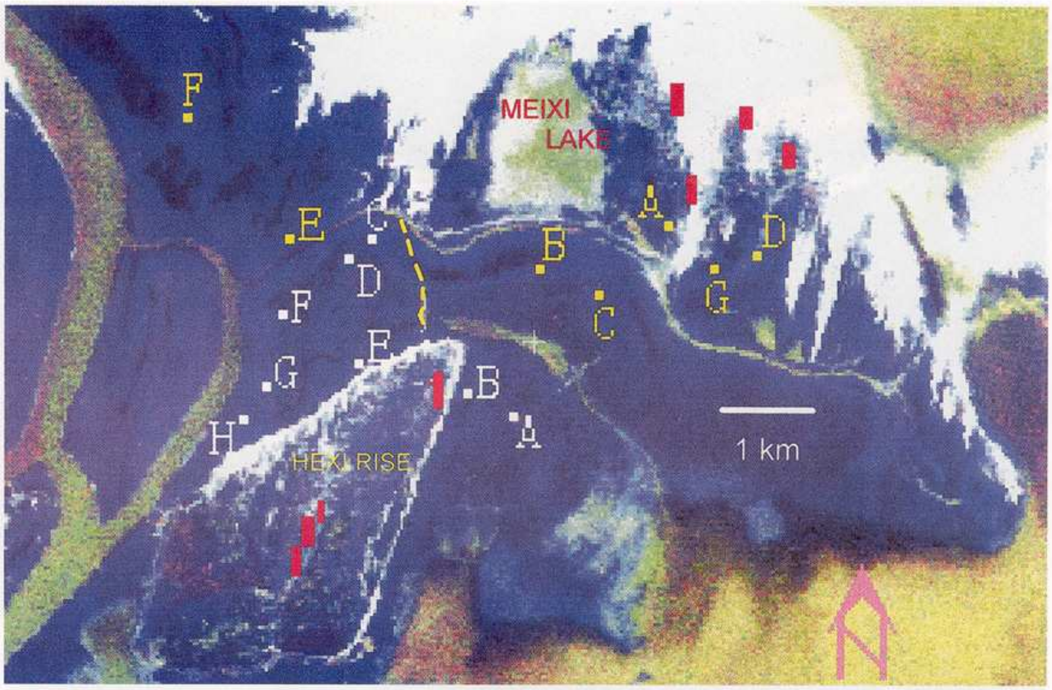

FIGURE 1. Remote sensing image with geographic information system data computer-mapped. Natural villages are the **bright red** rectangles. To the left of the **F** is Chang Lake **(dark purple).** The greenish tell-tail signs of pools of water in Meixi Lake are seen. In the Hexi-Jishan land mass investigated, the sites labeled with **white** letters are in Hexi Village, while those with **yellow** letters are in Jishan Village. The **white** areas are sand. The arrowhead-shaped bluff (Hexi Rise) of Hexi village is outlined in sand, with its tip pointed towards Meixi Lake. The Meixi Lake basin is surrounded by sand. The Gang River (**greenish** ribbon) is to the left with the loop that swings by the Chang Lake range, (**yellow,** E and F) and then past the Hexi Houshan range (**white,** F–H). The small river connecting the loop of the Gang River to Poyang Lake to the right passes by sites E, B, C, and G (**yellow** letters).

Figure 24 Study area view by remote sensing

RS images

Figures 24-27 are Landsat images of the four villages taken on April 6, 1999 when the lake was at its lowest level. The RS images were geocoded and analyzed using PCI Geomatics Corporation (Richmond Hill, Ontario, Canada) software. The images were visually classified to show water, grassland suitable for snails, wet marshy-muddy areas, mud flats, and agricultural highland areas. The color spectra have been arranged to PCI channels 2, 3, and 5 for optimal visual classification. The spectral screening used for all these RS images gave the following results. Water ranges in color from bright yellow (open lake water or reservoir water) to greenish-yellow or green (shallow water or flock-laden shallow water) to yellow grading into red-maroon (shallow water over mud flats or very wet mud flats). The blue color indicates grasslands used for grazing and suitable for snails. The very dark purple areas within the lighter blue are small pond basins that are grass choked and very wet, thus not suitable for snails. These are the first areas to fill with water during the rainy season.

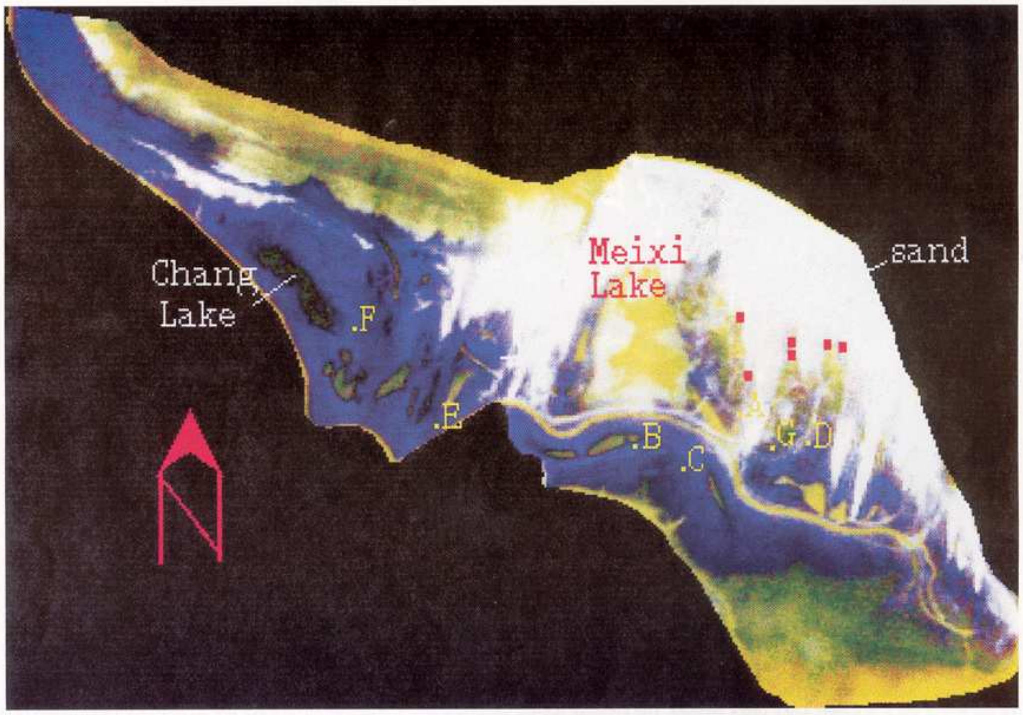

FIGURE 2. Remote sensing image with geographic information system data computer-mapped. A cutout of the Jishan land mass clearly shows different ecologic zones. Much of Jishan is composed of high sandy bluffs **(glistening white).** Water is **bright yellow,** while shallow water over mud flats is **greenish-yellow.** Those parts of the grazing range optimal for *Oncomelania* are **light blue** while the areas that are unsuitable are **blue-black.**

Figure 25 Cut out of Jishan land mass

The classified images were used to calculate the area of grazing land based on the number of pixels that we classified as grazing land. The landmass to be investigated (e.g., the entire grazing lands of a village) is called an LMU. In this procedure, the LMU is masked with a uniform color leaving only the grazing land open with its adjusted color spectra (dark or light blue). PCI software calculates the total pixels for the image including the number for the mask. The number of pixels for the grazing land suitable for snail habitat is multiplied by 900 (one pixel is 30m x 30 m) to yield an area in m^2.

Villages selected for the epidemiological study

The RS and GIS data were previously used to show all of Poyang Lake and the locations of the tour villages in the epidermiology study (Davis et al., 1999). The general conditions of the lake have been previously reported. The locations of collection sites (lettered squares) are shown in relationship to the natural villages and buffalo and cattle grazing ranges (Figures 24-27). The statistics for each village are given in Table 30. The total area of grazing land is 17.32 km2. The largest LMUs are Jishan (70%) and Hexi (21 %) (Figures 24 and 25). The villages of Hexi and Jishan are somewhat similar in ecologic complexity and thus are well paired as control and experimental villages. The same holds true for the smaller (in area) villages of Dahuang and Xinhua, which have the least ecologic complexity. Dahuang is different from the other three villages in that only cattle, not water buffaloes, are found there. Table 30 shows the coordinates for the 23 sites routinely collected in the epiderniologic study covering 330,000 m2.

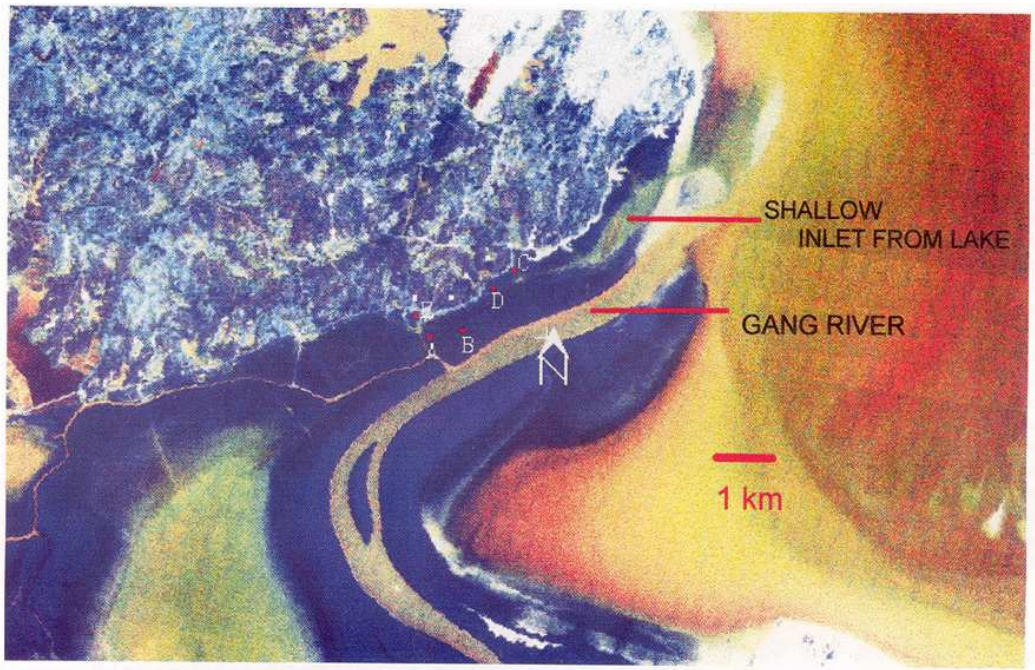

FIGURE 3. Remote sensing image of the village of Xinhua with geographic information system data computer-mapped. The **bright blue** grazing range suitable for snails is set off from the **yellow bands** of river and streams-inlets from the river. The bluffs are outlined in **white** sand-bare soil of the bluffs. To the left of the bluffs are the highlands, a mixture of villages and agricultural lands (top left quarter of the image). Mud flats and shallow water over mud and grass are the **greenish** areas that grade upwards into the grazing land. The Xinhua grazing range runs to the right of the inlet (**yellow** strip that runs from the river towards the bluff past letters **A** and **E**) to the right edge of the letter **C.**

Figure 26 Xinhua village

Hexi

The Hexi LMU, which is situated on an island, has six villages. The squares of Hexi have white letters. The grazing lands are the second largest of the tour (3.69 km^2) and support 364 buffalo. The villages are located on a prominent high, sandy, arrowhead-shaped rise (a small plateau) shown in Figure 24. East of this plateau there is a precipitous drop from the bluffs that run along the rise to the Shamo grazing lands (sites A and B in Figure 24) This semicircular region between the bluffs and the lake had an area of 1.63 km2. The grasslands, which are part of the village of Yuan Xia, are flat, covered with pools of water, and 15.2-15.6 m above sea level.

A cluster of small villages includes Hexi administrative village on the south-central part of the rise approximately 1 km from the village of Yuan Xia. Buffalo in this village exit by one of two paths (approximately 20 km) from the plateau onto the Houshan Grazing range (area = 2.06 km2) to the western part of the plateau (sites C-G in Figure 24). The grazing range slopes gently upward from the plateau towards the southwest to end at moderately high bluffs dropping down to a branch of the Gang River.

An inlet from the lake wraps around the northeastern end of the plateau and then narrows to a curving, narrow, creek like waterway running along the western edge of the highlands of the plateau and separated from it by 50--60 m. The major path from Hexi village taken daily by the buffalo reaches a dirt road that runs from the ferry landing on the Gang River at the southwestern end of the island to the edge of the plateau and along its western edge to the northeastern tip of the plateau. The western side of the plateau is entirely sand (the white border along the rise seen in Figure 24). Buffalo crossing the road and onto the grasslands wade through the above-mentioned creek with its marshy grasslands (site E in Figure 24). An earthen dike (dashed yellow line in Figure 24) runs from the inlet of the lake to a small branch of the Gang River, creating a boundary between Hexi Village and Jishan Village.

Houshan and Shamo are very different ecologically. The former had a higher elevation (17 m) and diversity of environments ranging from drier grasslands towards the river to marshy wetland along the inlet of the lake. Shamo is a uniform, flat, low, marshland with approximately the same elevation as the lake. It is rapidly covered with the first appearance of the spring flood.

Jishan

Jishan (Figures 24 and 25), directly north of Hexi, has four natural villages and is shaped like the head of an elephant with the "forehead and trunk" comprised of high sandy bluffs (gleaming white in the RS images). The entire grazing range had an area of 12.1 km2, the largest of the tour, and supports the greatest number of buffalo (665). There are three distinct zones in Jishan. Distances between squares (yellow letters) in these zones are greater than those in Hexi. A small and shallow "river" (dry during the fall and winter) runs between the Gang River and the lake, dividing the low- elevation grassland, which is similar to the Shamo grassland of Hexi. This grassland (zone I, Lousi-Xian grazing land) is bordered on the south by the lake and the above-mentioned dike at the northern end of the Hexi grazing range (Figure 25, sites B and C; elevation = 15.8-16.3 m). Zone I is a low, flat, grassland punctuated by pools of water comparable to the Shamo range of Hexi Village. Across the river to the north of Zone I is the Meixi Lake in the Dong He village area (zone II, site A, elevation = 15.9-16.0 m;

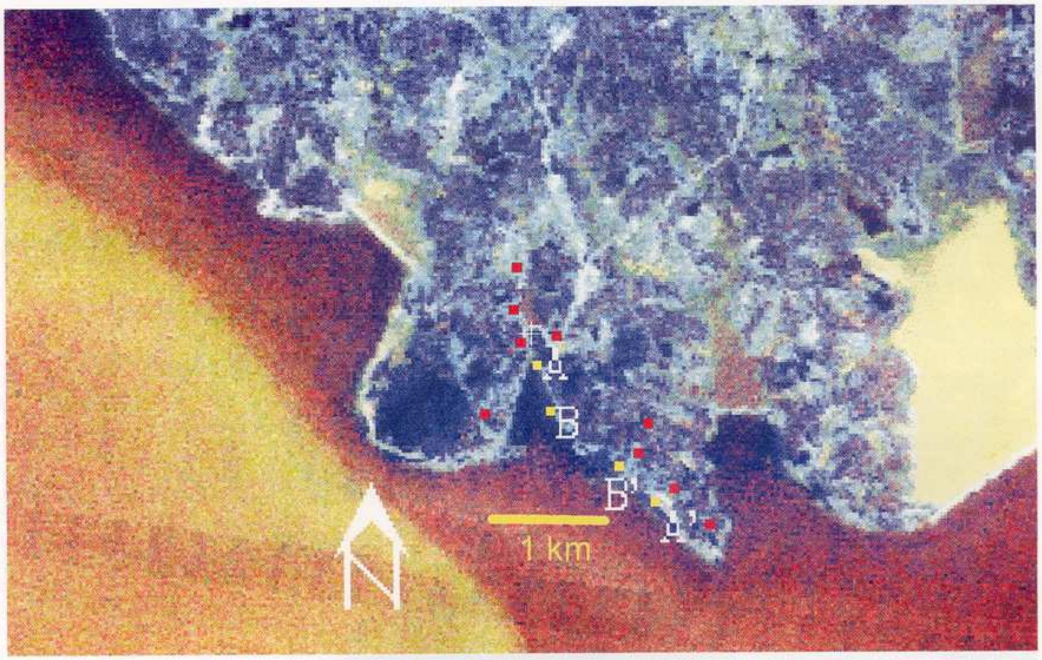

FIGURE 4. Remote sensing image with geographic information system data computer-mapped. The Dahuang land mass that was investigated is so small it cannot be shown at a scale suitable to adequately portray grazing lands as shown in Figures 1–3. The **dark blue** filling the arrowhead-shaped valley is grazing range. The grazing land continues as a narrow strip down along the eastern line of bluffs of the peninsula jutting out into Poyang Lake. The collecting sites are the **yellow** squares. From top to bottom they are A, B, B′, and A′. Natural villages are represented by the **red** squares.

Figure 27 Dahuang land mass

sites D and G, elevation = 16.4-16.7 m). Meixi Lake is a large and prominent area readily seen in RS images. To the west of it is a wide swath of sand running from the little river north to the high sand bluffs seen so prominently in RS images. Meixi Lake was full of water a few years ago, but is considerably reduced in volume today. East of the lake, the villages are situated on the high ground overlooking the Hexi grazing land. Below the villages are sites A, G, and D. At the east end of Meixi Lake is a village that was part of the initial epidemiological study. However, following the 1998 flood, it was abandoned due to vulnerability to flooding. There is a school at that village. Between the school and the lake, close to the lake, is site A. Grasses of the Meixi Lake range, as it slopes gently down towards the connecting river (between Gang River and the lake) grow on abandoned rice fields, a testament to the fact that the lake level has risen over the past decade. The area west of Meixi Lake, beyond the sand barrier, is the Chang Lake range (zone III). There is a footpath from the

Jishan villages to the loop of the Gang River that swings east from the maim river channel past the Chang grazing range. During low water, boats can maneuver and tie up next to the Chang range. The ecology of this section of grazing range is different from the others in that a vast area around Chang Lake had a low elevation with dense grasses emerging from standing water, a habitat unsuitable for snails, hut good for grazing buffalo. However, along the path to the boat landing, is site E (elevation = 17.3-17.4 m), a hot spot for infection. In Figure 25, the Jishan LMU had been cut out from the overall RS image. The color spectra delineate the different environments. The immense area of sand is glistening white. The meandering small river connecting Poyang Lake to the Gang River is clearly seen (yellow), separating the Xian-Lousi grazing range towards the bottom of the picture from the Meixi Lake-Dong He range. The extent of the grazing land that is suitable for *Oncomelania* is bright blue. Dark blue is shallow water over grass, a habitat unsuitable for snails.

Xinhua

This administrative village (Figure 26) had a small grazing range (1.18 km^2) and few buffalo (168). The grazing land, the lowest of the four grazing lands (elevation = 13.2- 15.0 m), is a narrow strip between the high bluffs (2: 15 m high) that parallel the Gang River and the river. It was severely impacted by the 1998 flood as discussed earlier. There are 19 natural villages clustered along the bluffs with approximately three or tour pathways down to the grazing land for the buffalo. A stream flows along the grazing land parallel to the bluffs about a fifth of the war between the bluffs and the river. Sites A and B are between the stream and the river (elevation = 13.2 m); sites C-E are between the bluffs and the stream. Site E, a hot spot that has the highest elevation on the Xinhua grazing lands (15.0 m), is located at the base of the bluffs at the western edge of the grazing range. The extent of the Xinhua grazing land is to the fight of the inlet from the river (yellow line running from the river towards the bluffs past sites A and E) to an area just to the fight of letter C.

Dahuang

Dahuang Administrative Village (Figures 27 and 28) consists of 12 natural villages positioned at various places along the bluffs overlooking a narrow bell-shaped valley through the middle of which flows a small stream. The Daquian grazing range (sites A and B) is on either sides of the stream that runs north to south down the center of the valley. At the southern end of the stream, where it enters the lake, the grazing lands and line of bluffs bends to the east. This eastern extension of the grazing land is the Dawanli grazing range (sites A' and B'). Together, these ranges, the smallest of the tour (only 2%) of 0.35 km2, support 168 cattle. The valley is narrow and deep so that as one moves up towards the bluffs on either side the land becomes drier and the grass more sparse. Snail habitat is restricted to areas around the stream and pools of water where there is lush grass and marshy areas. As a result. the area suitable for snails is limited. Elevations range from 13.5 m at the lake edge to 15.9 m towards site A).

Dahuang differs from the other three administrative villages in that there are no buffalo here, only cattle. The small area suitable for grazing and agricultural practices here preclude buffalo. As a result, there is no individual (cowboy) to take the cattle out to graze. Rather, members of an individual family take cattle out on the land each day. The range for grazing is limited to areas close to the local village. As a result, Dawanli range villages will not take cattle over to the Daqian range. Accordingly, in this administrative village, the position of the village relative to the grazing land might play an important role in the prevalence of infection in any One natural village. Following the 1998 flood, a new village was established (in 1999, after the epidemiological study began) on the bluffs above the Dawanli Grazing Range. The occupation of the villagers of this new village is fishing. Their boats are moored directly out from the village and villagers walk through a marshy hot spot to get to their boats.

The Poyang Lake tropical medicine research center snail survey method

The following questions concerning the distribution of infected *Oncomelania* were addressed. 1) What is the area of the grazing range of buffalo and cattle for any one village? 2) What is the distribution of snails throughout the grazing range? 3) Given the heterogeneity of large grazing ranges what is the mean density and variance in density of *Oncomelania* in different sectors of the grazing range? 4) What are the infection rates in the snails? 5) How much of the grazing land has no snails? 6) After observing the daily rhythms of cattle and humans, can one formulate hypotheses about where "hot spots" for transmission might be located? (Hot spots are optimal transmissions sites where one would predict that transmission occurs because of three factors: an ideal habitat for snails, the regular convergence of buffalo and cattle at the site, and close proximity to humans with regular human contact with water.) 7) How do temporal patterns in temperature, rainfall, and flooding affect all of these factors?

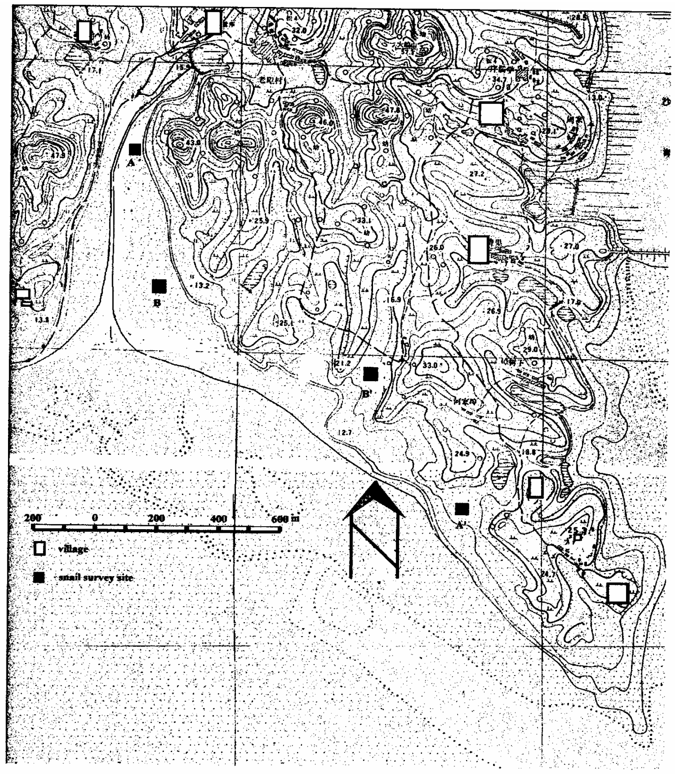

FIGURE 5. A digitized map of Dahuang showing in detail what could not be clearly shown in the remote sensing image. The filled boxes are locations of squares; open boxes are natural villages.

Figure 28 A digitized map of Dahuang

Chinese traditional methods for surveying large areas for snail density and infection do not serve to answer a number of these questions. The handbook for schistosomiasis control details procedures used throughout China for the past two or more decades in sampling areas for estimating snail density and infection rates in snails (Anonymous, 1990). A major problem is that *Oncomelania* snails have an highly clumped distribution that yields an immense negative binomial distribution (the standard deviation greatly exceeds the mean) when the sampling is clone the traditional way using a kuang frame, which had a small area of only 0.11 m2.

A negative binomial distribution for Poyang Lake had been documented (Zhang et al, 1990). Other studies have also reported this negative binomial distribution in China (Cao et al, 1994; Chen et al, 1980; Xie et al, 1980). One is also referred to the statistical work of Bliss and Fischer (Bliss et al, 1953). Routine collections using the traditional methods yield a disproportionate number of kuang frames with no snails or only one snail.

We devised a sampling strategy to reduce the effect of the negative binomial so that statistical tools could be applied to the data, such as analysis of variance (ANOVA), and information could be obtained regarding the distribution of infected snails. An LMU is the entire grazing land in a village. The areas vary but are typically 1-2 x 106 m2. The fundamental areas to be sampled on an LMU are 10,000 m2 squares (Figure 29). The location of squares on the LMU is first estimated using a topographic map with the locations chosen to sample representative areas of the LMU. The topographic map makes clear the shape and complexity of the LMU of concerned. The more complex the LMU in shape and variety of elevations and water inclusions such as ponds, inlets from the lake, etc., the more squares are needed to sample the variety of habitats. For example, Hexi and Jishan had the most complex topology of all the villages with regard to grazing land and the largest areas; we could sample this complexity with seven or eight squares (we added square H for routine sampling later).

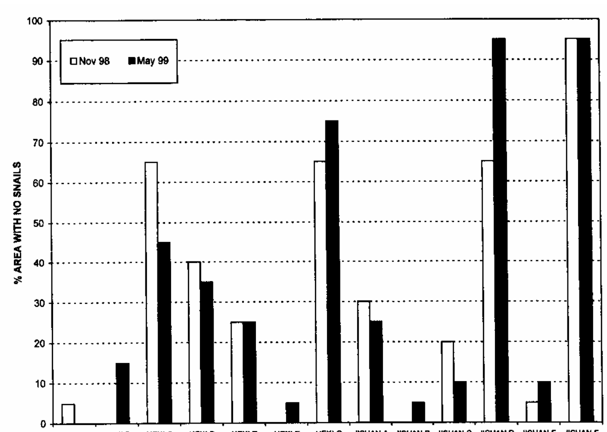

FIGURE 6. Areas of each square that do not have snails. Area is based on the number of cells (10 × 10 m) of 100 cells of a square that do not have snails based on the collections from a 4 m^2 frame placed in the center of each cell. The x-axis shows the lettered squares collected in Hexi and Jishan villages in two seasons (see the location of lettered squares in Figures 1,2).

Figure 29 Areas of each square that do not have snails

Habitat diversity on Poyang Lake marshlands is readily categorized. Habitats are 1) flat low marshlands with intermittent pools of water (>15.6 m elevation), 2) marshlands bordering rivers or inlets from the lake, 3) marshlands with some areas covered by a shallow depth of water (5-10 cm) with emergent grass, 4) elevated marshlands that are devoid of standing water, 5) marshlands that were recently farmed (e.g., for rice) but are no longer suitable for farming due to elevated lake levels (frequently close to a village), and 6) marshlands bordering a stream.

From our early experience in Hexi, we found that a square for each 0.5-0.8 km2 of a given habitat type gave good results, i.e., adding more squares would not provide greater statistical significance (e.g., some squares in the Hexi Houshan grazing range have proven to be redundant). We placed at least two squares in each habitat type of the administrative village. In Dahuang, we used two squares in the two sections of the grazing range even though this involved a square for each 0.09 km2. In the field, the exact locations may be shifted somewhat to be positioned on land that might support snails. Only areas that could harbor snails are included as potential sites for squares. We selected 23 squares and these are listed in Table 30.

The square is marked off in 10 m intervals to form a grid of 100 cells. A random number generator (calculator) is used to select 20 of the 100 m2 cells to be sampled. Twenty cells were initially chosen as an optimal number for random sampling with regard to percentage of area covered and constraints of time and labor to do the work. Initial experience with 20 cells yielded results that indicated that one would not obtain significantly different results with three or four fewer cells, and that adding more cells would likewise not significantly change the results.

A 4 m2 frame (area = 36.36 kuangs) is placed in the center of the selected cell. We chose this size frame because our experience with collecting *Oncomelania* in the field indicated that this area scale was optimal in including clumps of *Oncomelania*, whereas the kuang frame has too small an area, resulting in many kuang frames with no snails or only one snail, similar to the traditional transect method of collecting used in China. The 4 m2 frame is not too large to make collecting all snails in the frame a difficult and time- consuming a task, and the results show that sufficient clumps of snails are collected to decrease the effect of the negative binomial so that meaningful statistics can be applied to the results.

All snails collected from a cell are placed in a numbered packet. A global positioning system (GPS) reading is recorded from the center of each frame, enabling a GIS analysis at a later time. At the end of each day, all snails in a packet are crushed and the number of living snails is recorded along with the number of snails infected. Snails are scored for both schistosome and non-schistosome trematode infections. Results are reported here only for the schistosome infections. The comparative result involving non-schistosome infections will be published after the study is completed.

Each 10,000 m2 square is measured using a rope. Bamboo stakes are used to mark off 10 m lengths. The 4 m2 frame is made of bamboo and cord. These materials enable easy portability in the field. All snails in a frame are readily and quickly collected using a team of 4-5 local helpers.

From the data collected at each LMU, we calculated 1) the percentage of land with no snails (e.g., if five of 20 frames have no snails, 25% of the square is considered to have no snails, and 25% of 10,000 m2 is estimated to have no snails; the average is calculated for the entire 10,000 m2 square); 2) the mean ± SD density of snails (snails/m2) found on land areas with snails; and 3) the proportion of infected snails (infected snails/m2) for land areas with snails. We also identified the areas of the LMU that are "hot spots" for infection. This particular study involves a temporal analysis of infection patterns over a tour-real period. Thus, it allows an assessment of the effects of environmental changes, season by season, and year by year on snail distribution patterns and densities relative to infection. The established squares are collected twice a year. The collections must be made when the temperature is >=10℃ because snails are inactive and burrow in th e soil to aestivate at lower temperatures.

After the first collection, the squares were slightly offset but with some overlap on the position to the first square to ensure that snails were not collected from precisely the same frame location each time, thus artificially causing a reduction in snail density.

The following on-site modifications are made at the time of initial sampling. 1) Although the LMU for each natural village studied for buffalo infections, human stool examinations, snail distributions, and infections is initially mapped out in the provincial headquarters, final fine adjustments require help of local villagers in the field. 2) The effective snail-buffalo area to be assessed is determined by the scope and range of activity of the buffalo in each natural village. The total land available may be 1 x 106 m2, hut the buffalo of a natural village may graze on only half that area; efforts on snails will be restricted to the half used by the buffalo (grazing range). 3) The activity scope of the buffalo must be done with the local cowboy who herds the buffalo in each natural village. The effective LMU and its grazing range is then mapped and its area is determined. Coordinates are made with hand-held GPS instruments. 4) In addition to the pre-selected squares, we routinely used special collections. The locality of these special collections comes from a hypothesis that a given location may be an optimal transmission site. An example is given from our study of Hexi Village. Each morning, the water buffalo are taken out to pasture by the cowboy; each night they are collected and brought back to the village. They exit and enter the village by a well-worn track. The morning dispersal, with animals fanning out onto the grazing land, and the evening aggregation produces a funnel-like effect. At the area of maximum convergence the buffalo cross a stream and fringing marsh that is ideal for snails. Such a convergence zone close to the village with a potential for maximum human-snail-buffalo interaction is ideal for an optimal transmission site. We collected >=2,000 snails (if possible) from a small area of approximately 900 m2 without concern for the exact area. The snails were then crushed to obtain the frequency of infection. If the sample has infections, we placed a square adjacent to the area of the special collection and obtained random samples to establish the density of snails/m2, etc.

13.5 Results

Grazing land and snail distribution patterns

Hexi and Jishan are analyzed together since they are contiguous, have the largest grazing ranges, and have the largest number of buffalo (Table 30). Xinhua and Dahuang are similar in having small grazing areas hut differ in two significant ways: the former has the lowest elevation and is situated along the main channel of the Gang River. The latter has a very small grazing range that is not suitable for buffalo. Cattle are pastured there (Table 30 and Figures 26-28).

The baseline data obtained from collections made after the 1998 flood (November 1998 and May 1999) showed that there was considerable variation between both sites and seasons in the percentage of land that does not have snails (Figures 29 and 30). Optimal habitats for snails had the smallest areas without snails;

e.g., Hexi sites A, B, and F and Jishan sites A, B, C, and E. Jishan site D had too dry an environment for snails and Jishan F site was too wet for snails.

Xinhua showed the effects of the 1998 flood that covered the marshlands for an unusually long time and where currents of the Gang River swept the grazing range adjacent to the river (sites A and B) clear of snails (lowest elevation in the entire study of 13.2 m). No data were recorded for sites A and B in May 1999 because the areas were again covered by an unusually early flood. Sites located slightly more inland towards the bluffs (sites C and D) were similarly affected. Site E, a hot spot, was not located until May 1999. Dahuang site A had abnormal areas without snails in May 1999 due to excessive amount of water in the area at that time.

Snail density was greatest in the same optimal sites for snails where most of the areas of the squares bad snails (Figures 31 and 32) and where the impact of the 1998 flood was minimal, e.g., Hexi sites A and B and Jishan sites A, B, and C. The greatest densities (> 201m2) were found in the Shamao grazing range of Hexi (sites A and B) and in the similar habitat in Jishan (sites B and C, 12-26/m2). The devastating effect of the 1998 flood in Xinhua is obvious (Figure 32). Site C in Dahuang had the greatest density for that village (> 151m2).

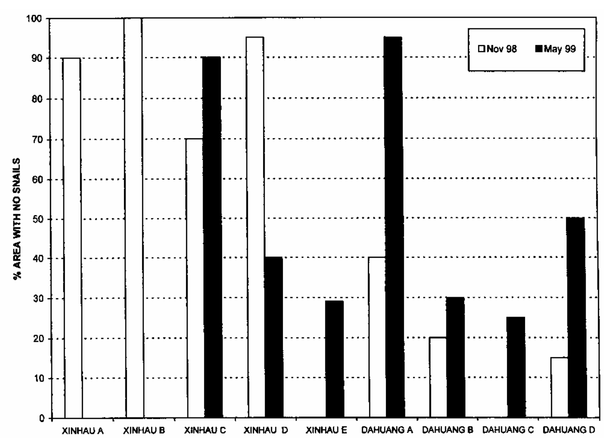

FIGURE 7. Areas of each square that do not have snails. Area is based on the number of cells (10 × 10 m) of 100 cells of a square that do not have snails based on the collections from a 4 m^2 frame placed in the center of each cell. The x-axis shows the lettered squares collected in Dahuang and Xinhua villages in two seasons (see the location of lettered squares in Figures 3–5).

Figure 30 Area of each squre that does not have snails

A significant seasonal difference in snail density is clearly seen in Hexi and Jishan (Figure 31). These villages, which were least affected by the 1998 flood and the early flooding in 1999 seen in Dahuang and Xinhua, presumably show a more normal affect of season on population structure. The seasonal affect is most pronounced in Hexi sites A and B, two of the most optimal areas for snails. Patterns in seasonal differences in Xinhua and Dahuang, should they occur or parallel the type of result seen here for Hexi and Jishan, will require at least 1-2 years without severe flooding to be observed.

The ranking of areas by snail density, based on the combined data from the November and May collections, is shown in Table 31. Only five sites bad high densities, i.e., > 28 snails/ m2. This involved 3,361 ±1,005 snails collected at these sites (only areas with snails). Density varied between November and May at 10 sites, and decreased over the winter. A site may have one level of density in November and a different one (usually lower) in May. In Xinhua, 80% of the sites bad low or negligible snails in both seasons, followed by Hexi (38%) and Jishan (29%).

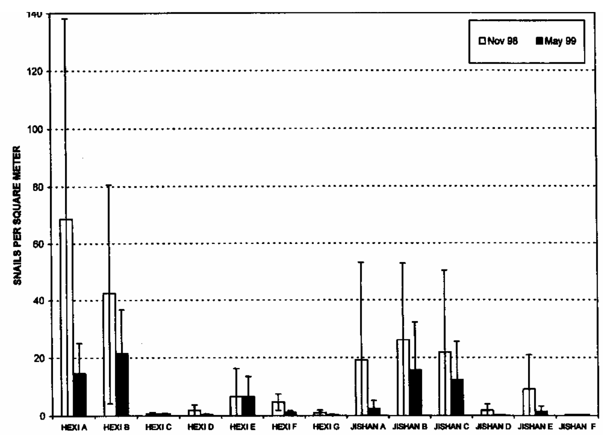

FIGURE 8. Sites (squares) in each village with mean ± SD number of snails/m² only for areas with snails. Area is defined as in Figures 6 and 7, except that cells with snails are used. The x-axis is defined as in Figures 6 and 7.

Figure 31 Snail sites in each village

Frequency of schistosome infections and hot spots

The frequencies of infection averaged over all areas where snails were found are shown in Figure 33. Frequencies ranged from 0.00 to 0.166 (an anomaly at site D in Xinhua because there was only one snail/m2 in 12 frames, and by chance two snails were infected). The upper frequencies of infection were 0.084 (Dahuang site A), 0.036 (Dahuang site D), 0.0194 (Jishan site D), and 0.0472 (Jishan site E).

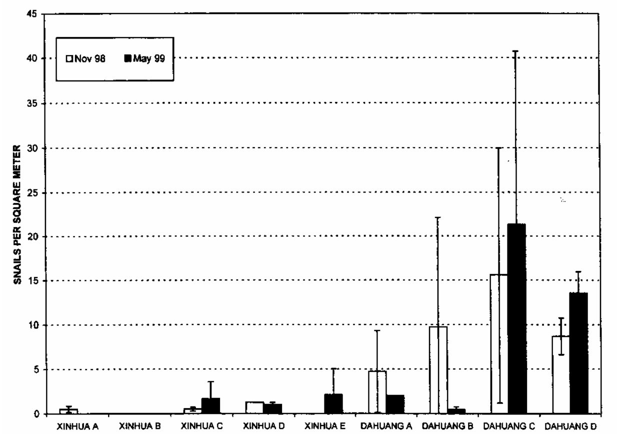

FIGURE 9. Sites (squares) in each village with mean ± SD number of snails/m² only for areas with snails. Area is defined as in Figures 6 and 7, except that cells with snails are used. The x-axis is defined as in Figures 6 and 7.

Figure 32 Snail sites in each village

When the data are limited to hot spots (Table 31 and Figure 34), the frequencies were much higher. Overall, the frequencies were higher in the May collections. In Figure 33, the high value for Xinhua was due to the anomalous frequency mentioned earlier. In Figure 34, there was only one hot spot in Xinhua (site E), and an SD for Hexi cannot be calculated because n = 2. There was no correlation between hot spots with high frequencies of infection and density of snails (Table 31).

Table 31 Ranking areas in terms of snail in terms of snail density

TABLE 2

Ranking areas in terms of snail density

Density	Range/m²	Mean/m²	SD	Mean number of snails collected*	SD	Number of squares
High (H)	> 28	43	15.4	3,361	1,005	5
Medium (M)	10–27	16	4.5	1,212	1,057	22
Low (L)	2–9	4.6	2.5	250	205	19
Negligible (N)	< 2	0.8	0.3	35.6	38.8	8
Squares	Hexi	Jishan	Dahuan	Xinhua		
A	H	M, L†	M	N		
B	H†	H, M	M, N†	N		
C	N	H, M	H, M (A′)†	N		
D	M, N	M, L	M, L (B′)†	L, N		
E	L†	L, N†		M†		
F	L	N				
G	M, N	M, L†				
H	M					

* Total number of snails collected from all frames of a given square that had snails.
† Hot spots.

There was a strong positive correlation between hot spots and the short distance from human activity and where buffalo converged twice a day near human dwellings or human activity (r > 0.80).

13.6 Discussion

Several major finding emerge from this baseline data set involving the first year of a four-year study. 1) Remote sensing enables one to classify grazing land, calculate its area, and differentiate habitats suitable for *Oncomelania* within it. 2) A method for collecting snails by random sampling has been used to identify areas that do not have snails, calculate the density of snails in areas in which they are present, and track the impact of seasons and environmental change on snail distribution and density. 3) Grazing land and snail habitats have been partitioned to enable an assessment of the patterns of distribution and density of snails, as wail as frequency of infections as they relate to land topology, ecologic conditions, and use of buffalo and cattle by humans. 4) The new sampling method reduces the effect of the negative binomial so that statistical tests such as ANOVA (structured for a negative binomial distribution) can be carried out. 5) There is a strong correlation between distance and optimal transmission sites. The shorter the distance between optimal snail habitat and human/buffalo and cattle interaction, the greater the probability of encountering a hot spot. 6) There is no ecologic stasis on the Poyang Lake marshlands. The significant intersite and inter-seasonal variation is much greater than had been anticipated. The variance in timing of the annual floods and intensity of flooding has a much greater impact on some sites than on others. The considerable yearly environmental variance requires a time-series study to assess long-term trends affecting disease transmission.

The baseline data demonstrate the considerable heterogeneity among different village grazing areas with regard to both snail distribution and infectivity frequencies. Snails have a highly clumped distribution even within grazing lands that would appear, according to RS images, to be suitable for snails. Three environmental factors have an impact on snail populations every year. 1) Water levels in the lake may vary considerably between years and seasons. Optimal snail habitat occurs in a very narrow zone of elevation above mean low water. Additionally, the annual floods drown many if not the majority of adult snails. The longer the floods, the greater the negative impacts on the snail populations. *Oncomelania* hupensis hupensis in this environment lives approximately one year. Elsewhere, where there is no flooding, the species can live more than 2.5-3.0 years and up to five years. 2) Currents can transport snails in large numbers (Davis et al, 1999). Flood-driven currents can sweep areas clean of snails under extreme circumstances as seen in Xinhua sites A-D after the extreme flood of 1998. With time, such areas will repopulate and the percentage of land with no snails may decrease to virtually zero. This is now occurring at Xinhua sites A and B. Likewise, a receding flood can deposit snails transported from other areas onto grazing land; this is being observed at Xinhua site A in the second year of the study. 3) Temperature affects reproduction. If the floods cover an area for a long period of time and the soil and water temperature remain less than 10℃ in the early spring, reproduction is inhibited. In Poyang Lake, reproduction must occur primarily in April and early May, before the onset of flooding from late May to mid June. In the 1998 flood, the floodwaters rose early in the spring and the temperatures were unseasonably low. Again, Xinhua, with the lowest elevation of the tour villages, was the most severely affected. Elevation of marshland above mean low water is, over time, the most critical factor affecting the distribution and density of snails. Areas that are highly elevated so that there are no seasonal standing ponds or inlets from the lake may have sparse vegetation and few or no snails. Such areas are found in Hexi sites C, D, G, and H and Jishan site D. Snails cannot live if the elevation is so low that during the dry season a shallow layer of water covers the base of thick grass, e.g., in Jishan site F and in part of Hexi site F. Optimal areas for snails are those found in Hexi sites A and B and Jishan sites A, B, and C where there are expanses of flat land with numerous dry-season ponds and water courses and a carpet of thick grass cover. Ideal conditions for snails are found in areas at the boundary of streams or permanent ponds with abundant thick grass and moist, silt-rich soil. The thick grass and moist soil maintain an optimal shaded and humid microclimate.

It was observed that there may be significant differences in the same snail population between seasons. In optimal snail habitats in Hexi and Jishan, there was a decrease in snail density in the spring, after the winter period of subterranean estivation, which can be attributed to adult deaths over the winter. Since the procedures used do not collect baby to one third-grown snails, the data are a good reflection of only the adult population. Although there was an increase in the snail collections at Dahuang sites C and D in May, additional years are needed to assess the actual trend, given the negative impact of flooding on this 10w-Iying wedge of marshland and the effect on collections in both seasons.

It is now possible to define snail density. By excluding land that has no snails, one can obtain a realistic understanding not only of the patchiness of distribution hut of numbers that can be compared statistically. Only five of the 54 squares collected (9%) bad a high density (mean = 43 snails/m2). Four of these were in Hexi and Jishan on low-lying flat marshlands described earlier as optimal for snails. Forty percent of the squares bad a medium density (mean = 16 snails/m2). Only two squares (4%) bad a negligible density (<2 snails/m2). Densities frequently change between seasons. Only 20% of the squares maintained the same density between seasons, but 9% of these bad negligible densities, indicating poor or disturbed snail habitats. In ail cases where there was a seasonal change in density, it was to a lower density in the spring collection attributed to adult deaths over the winter. Although we established snail density categories (Table 31) for Poyang Lake, it remains to be seen how well these criteria will serve the rest of China.

The 1998 flood underscores the reality that there is no environmental stasis on Poyang Lake marshlands. The factors impacting mean low water and snail reproduction, density, mortality, and distribution are in constant flux. It will take a number of years of intensive study at the selected study sites to obtain a true understanding of the dynamics involved and the variances in the diverse factors considered. If the factors affecting snail distribution and abundance are analyzed with an understanding of the daily activity patterns of buffalo and cattle, one may accurately predict where to find infected snails. There were no infected snails at Hexi sites C, D, F, and G or at Jishan site F. One must look to optimal snail habitats where there is a regular pattern of visits by buffalo and cattle. Although Hexi site A is high-density snail habitat, the frequency of infection was only 0.0004 in November and 0 in May: yet the nearby Hexi site B was a hot spot. With knowledge of the daily activity scope of buffalo and cattle, we could predict where we would find optimal transmission sites. One looks for the association of 1) an area close to a village where 2) buffalo and cattle are funneled through, coming and going to the grazing ground where 3) there are ideal conditions for snails. Two hot spots were predicted for Hexi. Site B of the grazing lands of Hexi Shamo had ponds and marshy areas directly in front of the village on the bluffs above, with the sheds for keeping the buffalo each night directly below. Access to the Shamo grazing land leads directly across the marsh (Hexi site B). On the other side of the plateau, buffalo traveling along the main dirt load down to the Roushan range from the cluster of villages cross the marshy ground and creek-like inlet from the lake that is always full of water (Hexi site E). The area is ideal for *Oncomelania*. The buffalo dispersed to the grazing lands after crossing this potential hot spot. In Jishan, we predicted an optimal transmission site at Meixi Lake (site A) in the grasslands at the edge of the lake and near the school. Another special collection yielding a hot spot was made at site G, along a perennial stream bordered by a marsh with truck grass, in front of Dong Re village. At Xinhua, only site E is an optimal transmission site. It is near the base of the bluff near an access route for buffalo coming and going from one group of villages. It had at an ideal environment for snails.

Dahuang has a minimal area for grazing. The optimal transmission sites are obvious. In the central valley that constitutes the Daqian grazing range, there are a few marshy areas bordering the central stream that are ideal for snails (sites A and B). On the Dawanli range that parallels the lake, there are two areas where streams descend from the bluffs paralleling the lake. These streams form perennial marshy pools close to the lake bounded by thick marsh grass. These are ideal for snails (sites A' and B') and are frequently visited by cattle, cattle tenders, and fishermen crossing the ponds to get to their boats.

Not all hot spots are easily predictable. The Chang Lake site E was not expected since there was only flat, thick grassland far from the villages and without streams or pools of water at this location. This site would not have been discovered without use of the sampling method used. The microclimate was excellent for snails hut snail densities were low. A closer study of this site showed it to be next to a well-used path from the villages to a boat landing and mooring area. Human defecation in this site coupled with heavy buffalo use contributed to this being a hot spot for infection.

Overall, eight of the nine hot spots (89%) were predictable given that buffalo and cattle play such an important role in transmission. Given the large sizes and ecologic heterogeneity of the grazing lands, there are actually few optimal transmission sites, and as seen in Table 30, these hot spots constitute a fraction of the entire grazing ranges. This has important implications for control strategies.

Jishan and Hexi are ideal as a pair of study villages (one experimental and the other a control). They have similar ecosystems, are comparable in size, and are buffalo systems 80th have two or three optimal transmission sites and relatively stable snail populations. Their frequency of hot-spot infected snails is not very high (>0.04). However, the frequency is higher in Jishan, the experimental village, than in Hexi (<0.01). These frequencies are much higher than those found in areas with negligible infections, i.e., one infected snail in 1,000 snails collected (frequency = 0.001). It remains to be seen if the treatment of buffalo and humans in Jishan will reduce the frequency of infected snails.

While Xinhua and Dahuang are similar in having small areas, they differ in terms of other factors affecting snail populations. Dahuang, an experimental village, is a cattle system; thus, the relationship of the bovines to snail populations is different from that found in the other three villages. All areas that are optimal for snails have infections and all tour sites could be considered hot spots. However, early flooding in both 1998 and 1999 affected these populations, with the result that we could not collect all squares in 1999. The frequency of infection in the hot spots (0.05) was higher than that found in the pair of Hexi-Jishan villages. In contrast, flooding had heavily impacted Xinhau and most of the grazing land there may be marginal for snails for years to come. What makes this village a viable control site is finding a single hot spot in May that potentially is relatively stable for both snail populations dynamics and infection frequencies. This small area had the greatest frequency of snail infection found in this study thus far (> 0.055).

14 A Geographic Information and Remote Sensing Based Model for Prediction of *Oncomelania hupensis* Habitats in the Poyang Lake Area, China

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14.1 Abstract

A model was developed using remote sensing and geographic information system technologies for habitat identification of *Oncomelania hupensis*, the intermediate host snail of *Schistosoma japonicum*, in the Poyang Lake area, China. In a first step, two multi-temporal Landsat TM 5 satellite images, one from the wet and the second from the dry season, were visually classified into different land-use types. Next, the normalized difference vegetation index was extracted from the images and the tasseled-cap transformation was employed to derive the greenness feature. Our model predicted an estimated 708 km2 of the marshlands in Poyang Lake as potential habitats for *O. hupensis*. Near-ground temperature measurements in April and August yielded a range of 22.8-24.2° C, and pH values of 6.0-8.5 were derived from existing records. Both climatic features represent suitable breeding conditions for the snails. Preliminary validation of the model at 10 sites around Lake Poyang revealed excellent accuracy for predicting the presence of *O. hupensis*. We used the predicted snail habitats as centroids and established buffer zones around them. Villages with an overall prevalence of *S. japonicum* below 3% were located more than 1,200 m away from the centroids. Furthermore, a gradient of high-to-low prevalence was observed with increasing distance from the centroids. In conclusion, the model holds promise for identifying high risk areas of schistosomiasis japonica and may become an important tool for the ongoing national schistosomiasis control programme. The model is of particular relevance for schistosome-affected regions that lack accurate surveillance capabilities and are large enough to be detected at most commercially available remote sensing scales.

Key words: Schistosomiasis; *Schistosoma japonicum*; *Onchomelania hupensis*; Remote sensing; Geographic information system; Normalized difference vegetation index; Tasseled-cap transformation; Disease mapping and prediction; China

14.2 Introduction

Schistosomiasis japonica is an endemic parasitic disease in China that remains of considerable public health and economic significance (Ross et al., 2001; Chen et al., 2005). In 2002, an estimated 90 million people were at risk of acquiring the disease and 820,000 were infected (Chen et al., 2002). The geographical distribution of *schistosomiasis japonica* is largely confined to the Yangtze River basin, including

Poyang Lake. This lake, situated in the middle-to-lower reaches of the Yangtze River in the Jiangxi province, is the largest body of freshwater in China with a surface area of 4,647 km2 (Davis et al., 2002). Poyang Lake exhibits a large seasonal water level fluctuation. While it is flooded during the rainy season from April/May to October, up to 90% of its water is lost during the dry season from November to April, which results in exposure of vast grass-covered marshlands with an area of 1,334 km2 (Davis et al., 2002; Wu et al., 2002; Chen and Lin, 2004). These marshlands constitute a major schistosome-endemic site in China, and controlling the disease in these settings proved particularly challenging, due to difficult accessibility, high levels of re-infection and bovines contributing significantly to disease transmission (Wu et al., 1994; Hu et al., 2000a,b; Davis et al., 2002; Chen and Lin, 2004). At the end of 2002, it was estimated that 2.5 million people are at risk of *Schistosoma japonicum* in the Poyang Lake area, with 83,000 people and 3,872 bovines infected (Chen and Lin, 2004).

Previous research in the Poyang Lake area has shown that infection prevalence of *S. japonicum* among villagers is highly correlated with distance from residential areas to marshlands, and that the density of *O. hupensis* is positively correlated with the density of infected snails (Chen and Lin, 2004). The presence of snail habitats is governed by climatic and environmental factors such as vegetation, soil moisture and temperature. While the backbone of schistosomiasis control is praziquantel-based chemotherapy, snail control usually is employed as an accompanying strategy, particularly in high transmission areas (Chen et al., 2005). However identifying snail habitats requires considerable manpower and some areas are difficult to access, especially during floods. For example, the 2001/2002 snail survey in Poyang Lake was carried out by 500 trained workers and took several months to be completed.

The development of geospatial technologies, notably remote sensing (RS) and geographic information systems (GIS), provide useful tools for determining environmental factors related to the distribution of intermediate host snails of schistosomiasis, and thus mapping and prediction of disease transmission (Brooker and Michael, 2000). Successful applications of RS and GIS techniques have been reported across different ecological, epidemiological and socio-cultural settings for the major human schistosome species, including *S. japonicum* in China (for reviews see Zhou et al., 2001; Yang et al., 2005a). For example, an annual mean temperature of 16-20℃, annual precipitation of 1,300-2,000 mm and 1,400-2,100 hours of total annual daylight were key environmental features for the presence of *O. hupensis* habitats (Zheng et al., 1998). The normalized difference vegetation index (NDVI), extracted from multi-temporal Landsat TM satellite images from dry and wet seasons, was used to identify potential snail habitats (Zhou et al., 2002a). Identification of *O. hupensis* habitats in the Poyang Lake area was done by means of unsupervised classification of Landsat TM images; the extracted land cover types correlated with snail habitats from historical surveys (Wu et al., 2002). Finally, an unsupervised classification employing Landsat ETM+ images, established different vegetation types that were correlated with snail habitats (Zhang et al., 2003).

In the study presented here, we developed a GIS and RS-based model to predict the distribution of *O. hupensis* habitats in the Poyang Lake area. The model combines two spectral processing methods, namely (i) a vegetation index (i.e. NDVI) and (ii) a tasseled cap transformation, for spectral feature extraction from Landsat TM 5 satellite images. They are utilized for identification of suitable conditions for snail survival. Ground-based field data were obtained for preliminary model validation. Model prediction was made for the risk of *S. japonicum* among local residents with particular consideration to the effect of distance from villages to marshlands.

14.3 Materials and methods

14.3.1 Study area

Poyang Lake is situated in the northern part of the Jiangxi province, bounded by latitudes 28°10’N and 29°50’N, and longitudes 115°30’E and 117°05’E (Zhang et al., 1998). The climate is humid subtropical with a strong influence of the East Asian monsoon. The mean annual temperature is 17.6℃ and the annual precipitation is 1,528 mm (Jiang and Piperno, 1999). The predominant vegetation is mixed deciduous-evergreen broad-leaved forest, with much of the southwestern coast of the Poyang Lake under cultivation, primarily rice (Jiang and Piperno, 1999). The Poyang Lake area is also a renowned bird sanctuary (Zhang et al., 1998). This lake is shallow (maximum depth: 21 m) and is connected with five main rivers, namely Ganjiang, Huhe, Raohe, Xinjiang and Xiuhe. Waters from these rivers run through Poyang Lake and discharge in the Yangtze River through a narrow passage at Hukou. The lake is surrounded by dykes with local communities living behind them or on islands either in the lake basin or outside. Villagers are primarily engaged in fishing and farming. Annual floods, beginning in late May or June and usually ending in October/November, fill up the lake, so that it swells into a large inland sea accessed by fishermen only. When the floods subside, the lake loses as much as 90% of its water, and hence vast areas of flat marshlands become exposed and are used for grazing by cattle and water buffalo (Guo et al., 2001; Davis et al., 2002; Chen and Lin, 2004).

There are 11 counties around the lake with Boyang, Duchang, Jinxian, Nanchang, Xinjian, Xinzi, Yongxiu and Yugan counties highly endemic for schistosomiasis japonica. The disease is reported from more than 1,000 villages in the Poyang Lake area (Guo et al., 2001; Davis et al., 2002). Table 32 summarizes the annual number of acute and chronic cases of schistosomiasis japonica reported in the Jiangxi province, and the surface area of the snail-infested marshlands.

Table 32 Annual number of acute and chronic cases of schistosomiasis japonica in Jiangxu province and surface area of marshlands

Year	Number of cases of schistosomiasis japonica			Surface area of marshlands (km^2)
	Acute	Chronic		
2000	62	121,725		687
2001	81	111,850		743
2002	146	128,331		761
2003	126	131,253		757

14.3.2 Image analyses

Two multi-temporal Landsat TM images of the Poyang Lake were purchased from China Remote Sensing Satellite Ground Station in Beijing. One was taken during the wet season in 1998 (25 August) and the other during the dry season in 2000 (16 April). Each image has a spatial resolution of 33 m on the ground at six of the seven bands. Band 6 thermal-infrared data has a resolution of 120 m (Beck et al., 2000). The images are centred on latitude 29°N and longitude 116°E (UTM, Zone 45).

The image analysis was performed in ERDAS Imagine version 8.4 (ERDAS, Atlanta, GA, USA). The images were visually classified according to typical land cover types and vegetation.. Once classified, the categories representing water and land were separated from the other classes. Flooded areas were determined by subtracting the dry season image from the wet season image. The resulting image indicates only the flooded areas and this was the area we considered for further analyses.

For identification of vegetation types related to *O. hupensis* habitats, two spectral processing methods were employed. First, the NDVI was extracted from the dry season image. It was calculated as the ratio between measured reflectivity in the red and near-infrared bands of the electromagnetic spectrum normalized by the sum of those bands. These two spectral bands are most affected by the absorption of chlorophyll in green vegetation and by the density of green vegetation on the surface. Second, the tasseled cap transformation, which allows the extraction of brightness, greenness and wetness of Landsat TS images that can express the majority of the total variability of an original image (Crist and Kauth, 1986), was used and the second feature (i.e. greenness) was extracted.

Near-surface temperatures for the study area were derived from the Landsat TM band 6 brightness, as described by Goward and colleagues (1999) and Gasch and Campana (2000), and pH values were obtained from existing records.

14.3.3 Snail surveys

Snail surveys were carried out at 32 locations around Poyang Lake in 1999 and 2000, adhering to standard procedures of the national schistosomiasis control programme (Anon., 2002). In brief, an area of 10,000 m2 was designated at each sampling location, and snails were searched for at 20 randomly selected points with a square method, covering an area of 0.11 m2. The number of snails collected in each sampling location and the number of positive snails were recorded.

14.3.4 Model development

Data from the snail surveys were used to determine types of land cover that were derived from the unsupervised classification and ranges of the values of the vegetation indices, which were most associated with the snail habitats. Then the results of the unsupervised classification were combined with the spectral features extracted from the multi-temporal images, i.e. the NDVI and greenness, the latter derived from the tasselled cap transformation. Finally, a composite model was developed for snail habitat identification. The model was based on the snail surveys done at the 32 locations.

Preliminary model validation was done with data from field surveys carried out at 10 locations, which were predicted as potential snail habitats, and are located in the north, centre and south of the Poyang Lake area. An additional evaluation of the model was performed by assessing whether the available near-surface temperatures and pH values were suitable for survival of *O. hupensis* in the habitats predicted by the model.

14.3.5 Risk assessment of *S. japonicum* infection

For spatial risk assessment of *S. japonicum* in relation to snail habitats, a GIS was established as follows. First, village-based *S. japonicum* prevalence data, obtained from the final cross-sectional survey carried out within the frame of the 10-year World Bank loan project for schistosomiasis control (Anonymous, 2002; Chen et al., 2005), were attached to the geographical coordinates of the villages. Second, the centroids of the snail habitats, as predicted by our model, were overlaid and buffer zones of either 600 or 1,200 m were applied. Spatial analysis was done using version 11.0 of the statistical software package SPSS (SPSS Inc., Chicago, USA).

14.4 Results

The unsupervised image classification showed that sparsely covered grasslands, and grasslands distant from water bodies are associated with the presence of *O. hupensis*. NDVI values at the identified snail habitats ranged between 108 and 139. In areas where rice growing is the primary agricultural activity, lower NDVI values were found with a range of 94-122. The large majority (96.3%) of the areas where snail habitats were identified had a NDVI in excess of 110. Hence, this NDVI value was designated as the cut-off to separate between presence and absence of suitable habitats for *O. hupensis*. This threshold, however, resulted in considerable miss-classification (i.e. 33.3%) of snail-free areas in rice agro-ecosystems.

Spectral image processing using the tasseled cap transformation revealed values of the greenness feature ranging between -88 and 48. Habitats of *O. hupensis* were restricted to values between -15 and 3. Agricultural land, primarily rice cultivations, exhibited values between -34 and 19. The large majority of snail habitats (i.e. 95.3%) had a tasselled cap transformed greenness ranging from -10 to 3, and only 7.1% of agricultural snail-free areas were within this range. Hence, we considered that the range of -10 to 3 has a good predictive ability to identify snail habitats.

By combining the above-mentioned conditions we developed a model, which identifies as potential *O. hupensis* habitats grassland areas with a NDVI above 110 and a greenness feature extracted from a tasseled cap transformation between -10 and 3. The model predicted 650,811 pixels, which in turn corresponds to approximately 708 km2 of suitable snail habitats, on the basis of an image resolution of 33 m. This result is in good agreement with the reported 687 km2 and 743 km2 of snail-infested marshlands in the Poyang Lake area in 2000 and 2001, respectively (Table 32). The proportion of pixels which are correctly identified as snail habitats is 94.9%, while the proportion of pixels which are correctly identified as snail-free is 93.1%. Figure 33 compares the distribution of *O. hupensis* habitats in the Poyang Lake area between the exhaustive snail survey carried out by the Jiangxi Institute of Parasitic Diseases in 2000/2001 and the predictions made by our GIS and RS-based model.

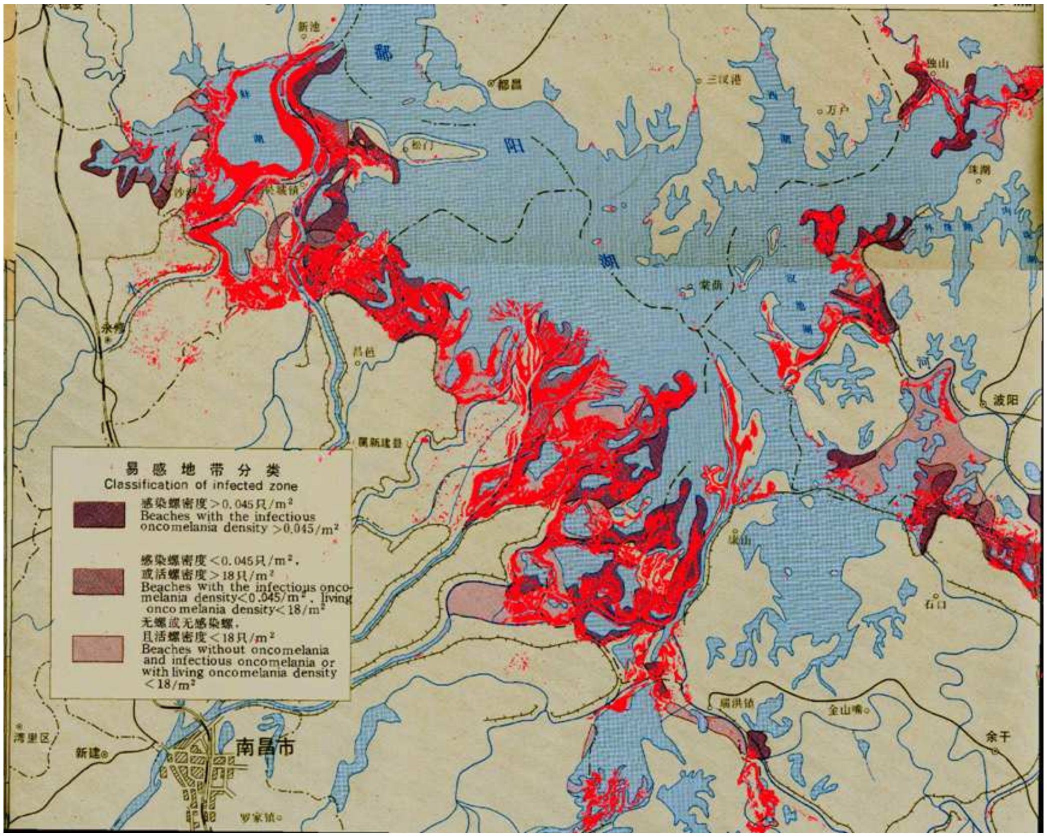

Figure 33 Comparison between the snail habitat distribution map in Poyang lake region and snail habitat by computer model

The near-surface temperature extracted from band 6 of the two Landsat TM images from those areas where the model predicted snail habitats ranged between 22.8℃ and 24.2℃. This is slightly higher than the annual mean temperature of 16-20℃, which has been identified as most suitable te mperatures for living and breeding conditions of *O. hupensis* (Zheng et al., 1998). However, somewhat higher temperatures were expected, as the two satellite images were taken in the months of April and August, when temperatures are above the annual mean. Extracted pH values from existing maps of the study area revealed values ranging between 6.0 and 8.5 for the predicted *O. hupensis* habitats, with the majority of the sites having a pH of 6.8-7.8.

The results of the preliminary model validation are presented in Table 33. Field surveys carried out in 10 randomly selected sites in the northern, central and southern parts of the Poyang Lake area, where the model predicted the presence of *O. hupensis*, indeed confirmed the occurrence of snails.

Table 33 Results of the malacological surveys carried out in 10 sites around Poyang Lake where the model predicted the presence of *Oncomelania* hupensis

Area	Points	Longitude	Latitude	No. of living snails	No. of positive snails (%)
North	A	115°55’57’’	29°15’37’’	23	0
	B	115°56’00’’	29°14’59’’	41	0
	C	115°55’47’’	29°14’35’’	12	0
	D	115°55’07’’	29°14’46’’	36	0
Centre	E	116°06’04’’	29°04’05’’	132	0
	F	116°05’10’’	29°03’28’’	14	1 (7)
	G	116°06’23’’	29°03’38’’	110	0
	H	116°05’41’’	29°02’59’’	31	2 (6)
South	I	116°07’23’’	28°57’40’’	86	0
	J	116°07’42’’	28°57’36’’	17	0

Villages with overall prevalences of *S. japonicum* ≥ 3% were primarily located within the 1,200 m buffer zones around the predicted snail habitat centroids in the Poyang Lake area (Figure 34). Conversely, most of the villages with *S. japonicum* prevalences below 3% were situated outside the designated 1,200 m buffer zones. Furthermore, villages of particularly high endemicity (*S. japonicum* prevalence ≥ 15%) were located within the 600 m buffer zones of the snail habitat centroids (Figure 35). Thus, a gradient of high-to-low *S. japonicum* prevalence was found with increasing distance from predicted snail habitats (Figure 36).

14.5 Discussion

The development of RS and GIS technologies and advances in spatial statistics are increasingly seen as powerful tools for a diverse set of applications across disciplines, including disease mapping and prediction at non-sampled locations (Brooker and Michael, 2000; Hay, 2000). Modern RS/GIS approaches have important advantages over conventional epidemiological sample survey techniques, which are often laborious and costly, as in the case of schistosomiasis. Hence, applications of these techniques have been suggested strongly for rapid identification of high risk areas, so that scarce resources for control can be allocated in an efficient, timely and cost-effective manner (Utzinger et al., 2003).

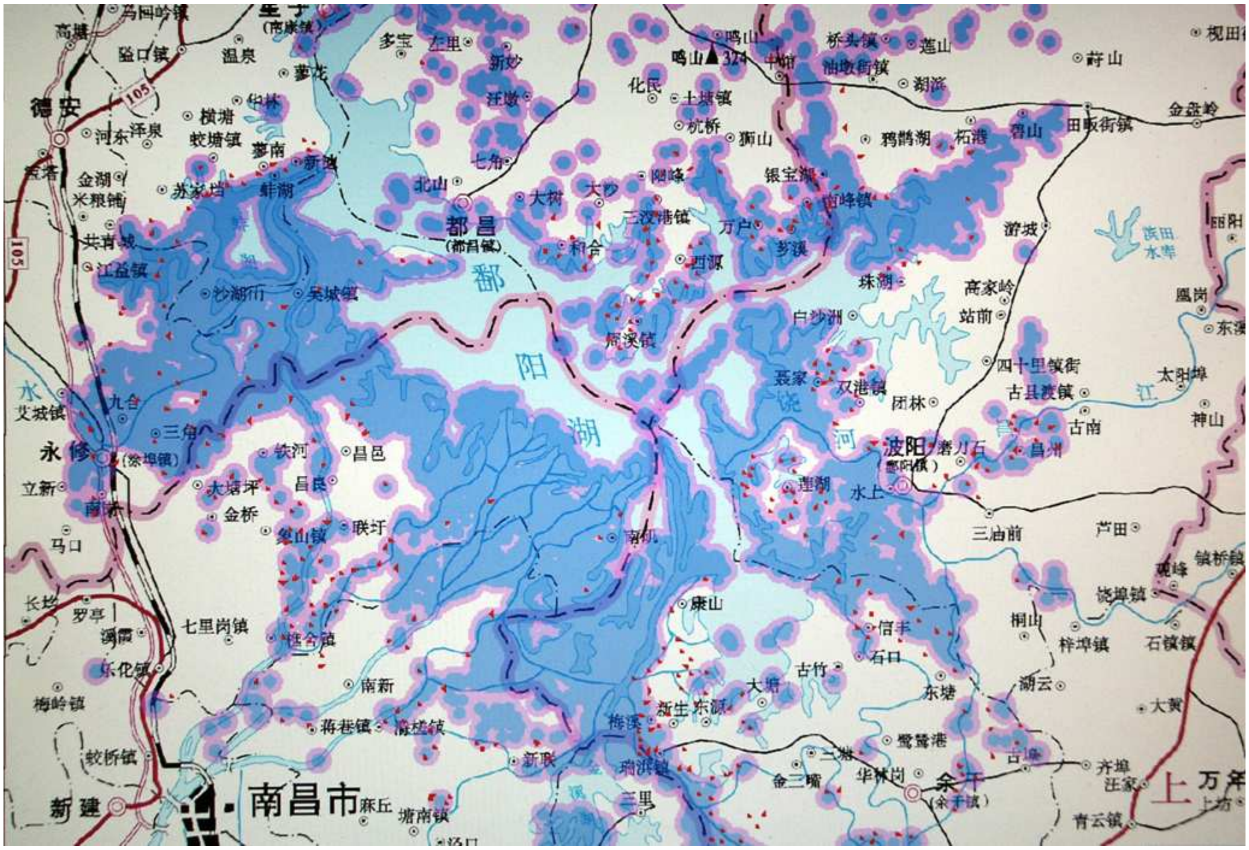

Figure 34 Map of the distribution of high prevalence villages in the Poyang lake region, (blue color shows suspected snail habitats, pink color shows buffer zone within 1,200 meter, and red points show the villages)

The development of integrated RS and GIS approaches to further our understanding of the epidemiology of schistosomiasis and to guide the spatial targeting of control has a history of more than 10 years (for an early publication see Malone et al., 1994). Subsequently, various models have been developed and successfully applied to map and predict the distribution of *S. mansoni* in Brazil (Bavia et al., 2001) and in various African settings such as Côte d'Ivoire (Raso et al., 2005), Egypt (Malone et al. 1997; Abdel-Rahman et al., 2001), Ethiopia (Malone et al., 2001) and Uganda (Kabatereine et al., 2004). Models based on an integrated RS/GIS approach have also been applied successfully for mapping the distribution of *S. haematobium* in Chad (Brooker et al., 2002) and Tanzania (Brooker et al. 2001), and hence to guide control interventions. Finally, an array of successful applications is reported for *S. japonicum* in China across different spatial and temporal scales. These include identification and prediction of suitable *O. hupensis* habitats at a small scale (Seto et al., 2002), mapping infection prevalence and intensity of *S. japonicum* at a large scale (Yang et al., 2005b), and predicting the effect of climate change and ecological transformation on the frequency and transmission dynamics of the disease (Zhou et al., 2001; Yang et al., 2005c).

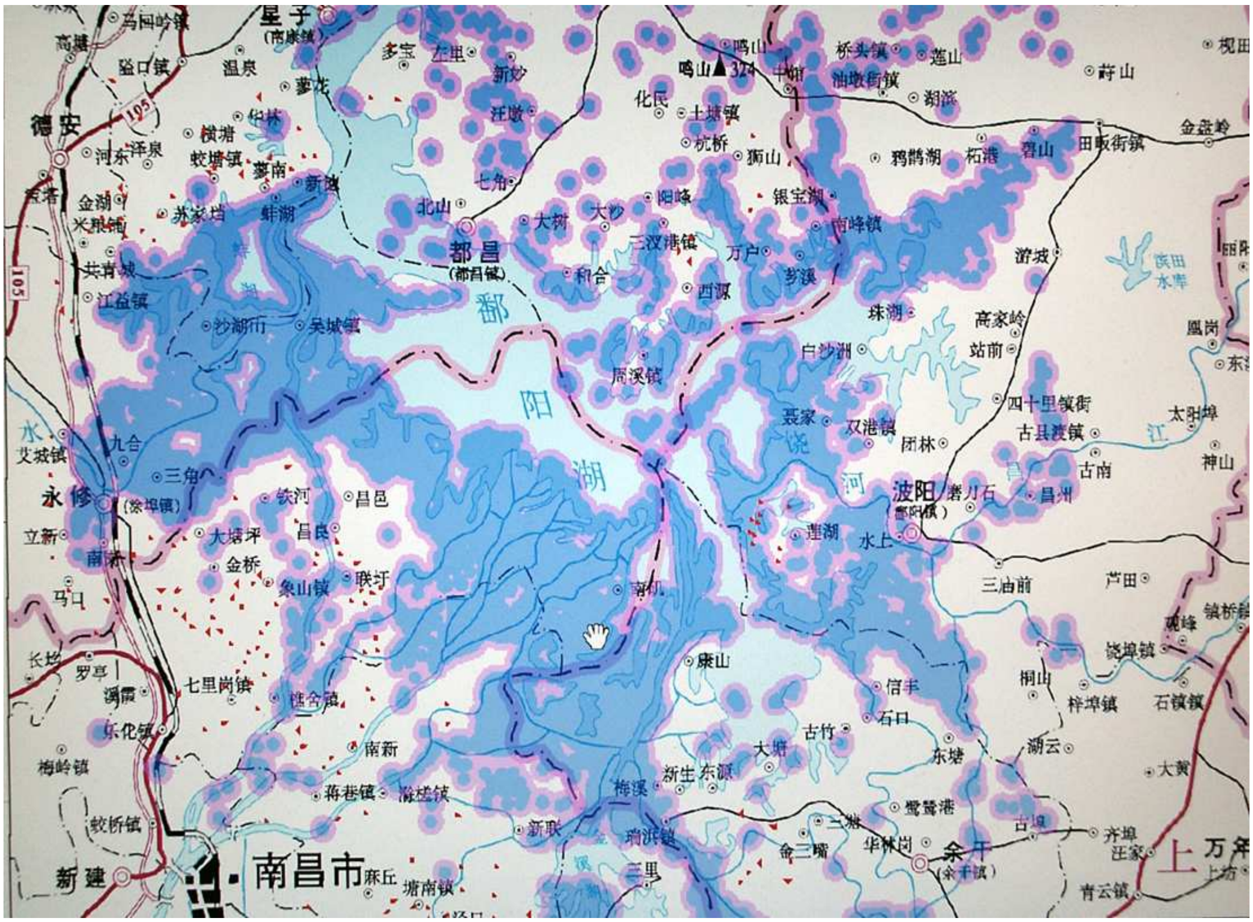

Figure 35 Map of the distribution of low prevalence villages in the Poyang lake region, (blue color shows suspected snail habitats, Pink color shows buffer zone within 1,200 meter, and red points show the villages)

In the present study, we combined RS and GIS technologies, supplemented with a simple spatial statistical approach to identify habitats suitable for *O. hupensis* in the Poyang Lake area, and to determine the relationship between distance from villages to predicted snail habitats and prevalence of *S. japonicum*. Two multi-temporal Landsat TM 5 satellite images, taken during the dry and rainy seasons, were visually classified into different land-use types, and digitally processed to extract NDVI and the tasseled cap transformation greenness feature. RS data from *O.*

hupensis habitats enabled us to determine conditions suitable for the presence of snails. By combining these conditions we then developed a model which identifies potential snail habitats according to the following two features: (i) grassland areas with NDVI greater than 110, and (ii) tasseled cap transformation greenness between -10 and 3. The model exhibits a high sensitivity (94.9%) and a high specificity (93.1%). In other words, the model is able to correctly classify *O. hupensis* habitats with an accuracy of 0.949 and predicts snail-free sites with an accuracy of 0.931.

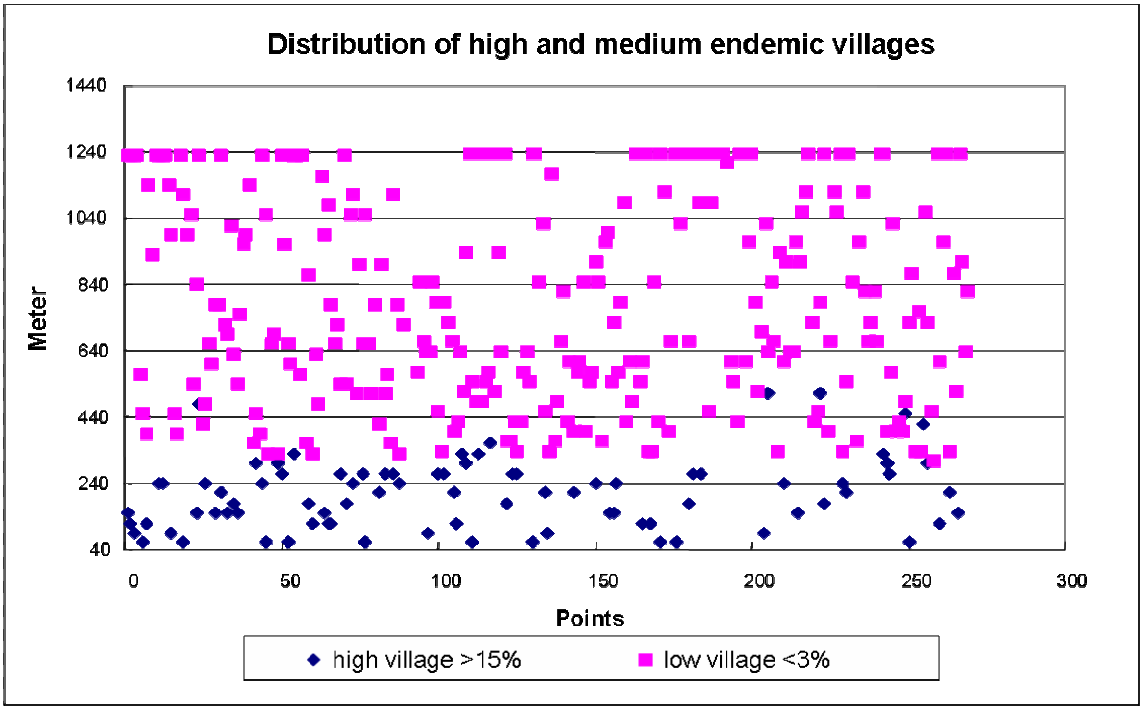

Figure 36 Graph depicting villages with prevalence of *S. japonicum* > 15% (blue diamonds), mainly located within the 600 meters buffer zone in the Poyang lake region and prevalence below 3% (pink squares).

In our earlier work we only used land-use classifications to predict *O. hupensis* habitats (Wu et al., 2002). That model also showed a high sensitivity (90%-95.6%), but only a moderate specificity (61.1%-68.6%). Thus by introducing NDVI and tasseled cap transformation greenness feature extracted from the satellite images, we were able to increase model specificity by approximately 30%.

The NDVI is the single most important vegetation index and has been widely and successfully used for prediction of intermediate host snails of schistosomiasis, and hence the mapping of the disease across different ecological and epidemiological settings (Bavia et al., 2001; Kristensen et al., 2001; Guo et al., 2002;

Zhang et al., 2003; Raso et al., 2005; Yang et al., 2005b). For the current setting, we initially hypothesized that the abundance of green vegetation could be used as a proxy for suitable *O. hupensis* habitats. Actually, 96.3% of the snail habitats corresponded to NDVI values greater than 110. However, it proved difficult to distinguish certain agriculture areas, namely rice agro-ecosystems.

To our knowledge, only few studies have used the tasseled cap transformation as a means of spectral feature extraction from Landsat TM images. In the current study and in our preceding work, we used the greenness feature extracted by this linear transformation method (Guo et al., 2002). Another group of researchers in China employed a tasseled cap transformation and modelled the distribution of *O. hupensis* in the marshlands with the use of brightness, greenness and wetness features (Zhang et al., 2005). Application of a tasseled cap transformation to multi-temporal Landsat images also proved useful for the detection of coastal saline land uses in Shangyu city, China (Zhou et al., 2002b).

Besides vegetation, key factors for survival of *O. hupensis* in the Poyang Lake area include elevation and soil moisture. Although the satellite image cannot recognize elevation directly, a high correlation among vegetation cover and elevation has been observed in marshlands that are prone to floods (Zhou et al., 2002b). Since we employed two Landsat images, one from the dry and the second from the rainy season, we could delineate the areas that were flooded by means of unsupervised classification. Similar to elevation, soil moisture cannot be measured directly by Landsat TM images. However, a wetness index can be extracted by the tasseled cap transformation (Zhou et al., 2002b; Zhang et al. 2005). Snail habitats can then be distinguished from agriculture areas, such as irrigated rice plots and dry farming.

Zhou et al. (2002a) developed a GIS/RS model for identifying snail habitats in the Poyang Lake area using land cover data and a square root transformation of the NDVI. The predictive ability of the model to identify *O. hupensis* habitats was over 92% in large marshlands and over 85% in medium-sized marshlands. This result confirms our earlier remark that the NDVI is a good proxy for vegetation coverage, but less so for soil moisture. Preliminary validation of our model at 10 randomly selected locations around Lake Poyang revealed the presence of snails in all 10 sites, thus confirming our model predictions.

Finally, preceding epidemiological and malacological work carried out in the Poyang Lake area suggest a strong correlation of the prevalence of *S. japonicum* and distance between villages and the main transmission sites (Chen and Lin, 2004). In this study, we created buffer zones around the centroid of the predicted snail habitats and showed that most of the villages with prevalences ≥ 3% were located within a 1,200 m buffer. Most of the high prevalence villages (i.e. prevalence of *S. japonicum* exceeding 15%) were located within a 600 m buffer. Those villages with low prevalences (i.e. < 3%) were located further than 1,200 m away. This finding indicates that our model can be used to predict the community risk of *S. japonicum* on the basis of snail distribution data. Hence, it holds promise for rapid identification of high risk communities in areas that lack epidemiological baseline data. It can also be used to capture temporal changes in schistosomiasis risk due to climate change and ecological transformations.

Acknowledgements

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15 Conclusions and Recommendations

Schistosomiasis remains one of the most prevalent parasitic infection in the world. It is endemic in 76 countries and territories, and continues to be a global public health concern in the developing world. It is estimated that 200 million people are infected, of whom 120 million are symptomatic and 20 million suffer from the disease. Six hundred million people are at risk of infection. The WHO report of burden of schistosomiasis with disability-adjusted life year (DALY) in the World (GBD 1990) show that the DALY is 1369 in Africa, 129 in Egypt, 73 in Brazil and 22 in China. The WHO has recently reviewed the strategy for the implementation of morbidity control in high burden areas and has put emphasis on better targeting of control interventions and on more cost-effective and sustainable implementation of control strategies.

In China, the endemic area of schistosomiasis is along the Yangtze River. By 2002, the transmission was interrupted in 247 counties out of 418 affected ones. In 63 counties, the transmission was under control, while in 108 counties, the disease was still endemic. The total number of infected individiuals was 820,000 and 90 million were at risk of infection. The areas covered by snail habitats were 3,436 million m^2 (Chen, 2002) located mainly around the lake regions of Hunan, Hubei, Jiangxi, Anhui and Jiangsu.

Jiangxi province is one of the most seriously endemic areas of *schistosomiasis japonica* in China. Poyang Lake in Jiangxi Province is unique. It is a typical marshland with schistosomiasis endemic areas. 79.45% of acute cases occurs there and 96.43% of the snail habitats are found around the Poyang lake region. After the World Bank Loan Project, the prevalence clearly dropped. However, the re-infection and new-infections rates are about 12-24% and 5 –12 % every year, respectively in the high endemic areas (Zhang et al, 2002). Many scientists are thinking about sustainable development of that region and explore rapid and effective methods to adapt to the requirements of morbidity control.

There is clear evidence from countries where the public health importance of schistosomiasis was recognized and schistosomiasis control implemented, that the WHO-recommended strategy for morbidity control is effective. Four national control programmes (Brazil, China, Egypt and the Philippines) can be cited where concerted control efforts, together with economic development, have decreased morbidity to very low levels (WHO, 1998). Although the mass chemotherapy plays an important role in morbidity control, some side-effects have to be considered, such as compliance of residents after frequent drug taking, cost of treatment and potential for drug resistance. Evidence suggests that vertical programmes, while initially successful, are generally not sustainable. Therefore, it is important that schistosomiasis control builds upon and strengthens the capacities of existing health services and national policies. Emphasis should be given to the integration of control and decentralization of decision-making and delivery. National policy makers and health authorities should recognize the local public health importance of the disease and give the necessary support to peripheral health services to deal with it. Primary health care services should be strengthen so that they are capable of carrying out control strategies.

The provision of basic clinical care is an essential component of control within the existing health system. In addition, health services should ensure more active morbidity control and implement appropriate treatment strategies whenever this is required. In China, most of the places where control efforts have brought schistosomiasis to low levels require maintenance of adequate resources to consolidate the benefits obtained by schistosomiasis control. Full attention should be given to the cost-effective use of available funds, and to maintaining high standards of quality in carrying out control interventions. Screening and treatment strategies should be adapted to the changes of the epidemiological situation.

In the first phase of this thesis, we summarized the Chinese experience of schistosomiasis control particularly the morbidity control strategy and some results of the World Bank Loan Project which was carried out in the past 10 years. During the period of 1981-1989, the number of acute cases were increasing year after year. After the 10 years morbidity control implemented as part of the World Bank Loan Project, the prevalence has been clearly reduced, especially in the lake regions (Chapter 4). But there are still problems. Results show that the coverage of mass chemotherapy in high endemic areas was reduced due to repeated yearly mass chemotherapy (Chapter 10). Schistosomiasis transmission still exists in most of the marshlands and bovines are very important transmission sources (Chapter 8 and

Chapter 9). The three Gorges Dam water concervation project introduced environmental changes which are related to transmission. Another problem is that the funds for schistosomiasis control will be reduced after the World Bank Loan Project (Chapter 4).

Schistosomiasis control existed nearly 50 years in China. In Chapter 5, we reviewed some changes of strategy of schistosomiasis control in China. The main strategy is mainly large scale snail control and elimination, supplemented with chemical mollusciciding. Since 80s, praziquantel has been introduced together with the highly sensitive and specific immuno-diagnosis technique. In areas with high transmission potential chemotherapy is supplemented with snail elimination.

Chinese scientists have done a lot of studies on field morbidity control approaches. Through those studies since late 1980s, a sound basis for schistosomiasis control has been set up (Chapter 6). Chemotherapy became mainstream in schistosomiasis control since the beginning of the World Bank Loan Project. Meanwhile, health education, health economics and environmental epidemiology developed rapidly, enriching the control strategy. A complete health system for schistosomiasis control was formed. People began to think about the cost-effectiveness, and evaluated each item of control activities as well as the whole strategy of control. The appearance of new prevention drugs such as artemether and artesunate will change the traditional approach of treating to rather preventing the disease. Combinations of praziquantel and artemisinin derivatives will produce new drugs for chemotherapy.

Recently, an integrated, multi- knowledge strategy has been developed in China, focussing on the individual protection and health education, environmental modifications, supplemented with safe water supplies and proper disposal of human excretions (Chapter 7).

Schistosomiasis control is complicated due to the vector-borne and zoonosis aspects. It needs a perfect plan which is long-term, cost-effective and available in the field. A good strategy should be implemented rapidly, it should be cost-effective, simple and acceptable for the users and providers. As we know, schistosomiasis control is influenced by economical, cultural, behavioral and social factors. Community effectiveness depends on the highest possible success rate for each step. This requires co-operative efforts of all those involved: scientists, managers, community health workers and last but not least, the community itself (Tanner et al., 1993). We face problems due to: financial shortage, large scale snail habitat, surveillance in medium and low transmission areas, compliance for mass chemotherapy, changes in the countryside economic system, grass roots institutional reforms. To overcome the problems, the following activities are to be implemented in the future:

- Strengthening control programs for morbidity control strategies in high endemic areas, and maintaining and consolidating their achievements. On one hand, in order to control effectively high endemic area, it is necessary to increase treatment coverage and effectiveness of chemotherapy. Besides health education and an increasing chemotherapy compliance, it is important to choose the timing of mass or selective chemotherapy in order to avoid the farming season (Chapter 10). On the other hand, passive chemotherapy can be used as the strategy for schistosomiasis control during maintenance and consolidation periods. It plays an important role on morbidity control in high endemic areas. Meanwhile, the passive chemotherapy can combine the Primary Health Care network system easily (Chapter 11).
- Strengthening scientific research and accelerating field applications. During 10 years, the Joint Research Management Committee (JRMC) made many achievements. Some projects solved practical problems directly, establishing strategies against schistosomiasis and developing diagnostic kits. Some projects have a greater influence in further research as it is the case for artemether. A lot of experience and clinical testing show that artemether has preventive properties against schistosomiasis. These findings are also likely to be of considerable importance for antischistosomal drug development. During the flood season, oral artemether was given to the people in schistosomiasis endemic areas of Poyang Lake. Data was shown that oral artemether has a promising effect on controlling acute schistosomiasis and reducing infection rates (Song et al, 1998). It has been also shown that artesunate was a highly efficacious preventive drug during the flooding of the Yangtze River in 1998. It was taken by 90,000 soldiers and cadres when they were fighting the floods, and it played an important role in protecting them from infection (Yuan et al, 2000). Artesunate can play an important role in schistosomiasis control by

reducing transmission and protect people. (Chapter 7).

- Strengthening the epidemiological surveillance in endemic regions, especially in lake regions in order to understand the temporal changes in transmission and prevalence. Two key factors can improve surveillance. The one factor is simple and rapid methods for identification of snail habitats. Using the traditional methods, during 2001 and 2002, snail identification of marshlands in Poyang lake required two years and 500 people. Furthermore some areas couldn't be accessed. The second factor is methods for more accurate estimation of the prevalence in a certain village. The standard approach is to check the prevalence records up to 5 years old. On the other hand a prevalence survey by immune-diagnosis, it could take as much as 4 years to finish in the Poyang lake region. The cost of snail survey was a third compared to the cost chemotherapy during the World Bank Loan Project (Guo et al, 1998). Both the surveillance and snail surveys need a new, cost-effective, available method to continue the work, particularly for the lake regions (Chapter 6).

Geographic information systems (GIS) and Remote Sensing (RS) can play an important role in the planning and evaluation of control interventions. Snail survival is linked to environmental factors which can be measured via RS. In the second part of this study, we developed a model based on GIS and RS which rapidly identifies snail habitats in the Poyag lake area (Chapter 14). Using RS and field data we established ranges of vegetation, soil moisture and temperature suitable for snail survival. NDVI is a very sensitive indicator for vegetation. Soil moisture cannot be measured directly, however, we used Tasseled Cap model which defines a wetness index related to soil moisture.We measure land surface temperature from data of band 6. Because the vegetation abundance varies with both elevation and submersion, TM images of the area taken during the wet and dry seasons were processed to mark the area where water and land were shifted during flooding using unsupervised classification. This model was further used to predict the risk of infection in the villages of the area based on the distance of the village from the transmission sites.

The diagnostic performance of water-contact patterns was characterized by high specificities but low sensitivities, hence negative predictive values. Water-contact patterns were more useful variables than anamnestic questions for schoolchildren's self-diagnosis of *S. mansoni* infection (Utzinger et al, 2000). Another key point is how to use the model to map the high risk areas for schistosomiasis control strategies. Traditionally, we estimate the prevalence of a village by its history record to decide either mass chemotherapy or selection chemotherapy. It is difficult to master the dynamic changes in the village with the yearly flooding. Schistosomiasis endemic areas are around the snail habitats in the Poyang lake region..

Based on these experiences and achievements with morbidity control of schistosomiasis, some exiting problems were emerged. These problems led us lead us to explore and further develop methodologies. In this study, we have successfully used the application of a compound model to identify snail habitats and use it as a method to assess the high risks of schistosomiasis transmission.

In China, although the morbidity control has been carried out for more than 20 years, the total number of infected persons was about 820,000 and 90 million persons were at risk of infection, and the areas of snail habitats were about 3.436 billion m^2. After the World Bank Loan Project, the prevalence declined. However, the re-infection rate and new-infection are very high in high endemic areas every year especially in lake region. In most low prevalence areas are maintained. So disease surveillance and snail survey are heavy work. In order to maintain and consolidate schistosomiasis control, we suggest: 1) to continue the mass chemotherapy in high endemic areas, in combination with health education, Primary Health Care systems and optimal treatment time for target populations; 2) to continue the selection chemotherapy in medium and low endemic areas, and to use passive chemotherapy consolidation and maintenance; 3) to use the GIS/RS mapping for high risk areas destined for mass chemotherapy before making a schistosomiasis control programme annually; 4) to use the GIS/RS to identify the high transmission sites and guide the molluscicide; 5) to use the GIS/RS to find and monitor new areas with snail habitats and high potential risk areas.

Three Gorges Dam is one of the greatest hydrodynamic projects in the World. It will be the same size as the Poyang Lake and could be in same situation as the Poyang lake region in the future. Environmental changes could bring about a new situation. Scientists are very interested whether Three Gorges become a new endemic area for schistosomiasis. Up to now many studies showed the snails to be either in Sichuan province (upper Dam) or in Hubei province (lower Dam). In order to monitor these areas, GIS/RS could be an ideal method to find mud and sand sedimentation, and monitoring marshland formation and suspected snail habitats.

A mathematic model showed that once a year mass chemotherapy in humans is slightly better in reducing human prevalence than twice a year. Depending on the heterogeneity of prevalence within the population, targeted treatment of high prevalence groups, with lower overall coverage, can be more effective than mass treatment with higher overall coverage. Treatment brings only short-term benefit since the prevalence rises to endemic levels once chemotherapy programs are stopped (Williams et al, 2002). Calculations based on the reinfection rate show that the prevalence could rise again to original levels in 3 to 6 years after the treatment was stopped (Zhang et al, 2002). As long as transmission continues, mass or selective chemotherapy will have to be repeated indefinitely.

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Field Photos

Photo 1 The dyke of Poyang lake, People live in the dyke

Photo 2 The grass of marshland in the Poyang lake region

Photo 3 Some marshland with seasonal agriculture

Photo 4 Buffaloes grazing in the marshlands of Poyang lake

Photo 5 *Oncomelania* snails in marshlands

Photo 6 Cattle crossing the river in Poyang lake

Photo 7 Fishermen living in boat

Photo 8 Women washing clothes in the lake

Photo 9 Snail surveys in the marshlands of Poyang lake

Photo 10 Field investigations

Curriculum Vitae

Personal Data

Name:	GUO Jiagang
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Present Since 2000 Senior Scientist

Department of schistosomiasis control, Institute of Parasitic Diseases, Chinese Center for Disease Control and Preventive

The Office of Surveillance and Monitoring on Schistosomiasis control, Ministry of Health

Secretary of Expert Consult Committee on Schistosomiasis, Ministry of Health

Functions:

Public Health Research

Consultancy work for Ministry of Health

Fields of work:

Projects on schistosomiasis control in China

Operational research of schistosomiasis including the cost-effective analysis and compliance of chemotherapy

Application of Remote Sensing in Poyang lake

Role of bovines in schistosomiasis transmission in Lake areas

Application of GIS and RS in Schistosomiasis surveillance and control

Professional Education:

Period	*Place of study*	*Subject*	*Qualification*
1977-1982	Jiangxi Medical College	Medicine	Diploma Medical Graduation
1985-1987	Jiangxi Teacher University	English	Diploma
1995-1996	Swiss Tropical Institute	HCMTC	Diploma
1995, Sept.	European Course in Tropical Epidemiology		Certificate
1998, Jan.	Swiss Tropical Institute	Health management	Certificate
1998, Nov.	The workshop in China	GIS/RS	Certificate
1999, Oct.	NASA/CHAART, USA	Remote Sensing	Certificate
2002, April	University of Queensland	Math. Modelling	Certificate

Professional Career:

1982-1989 Jiangxi Institute of Parasitic Diseases, Research Trainee
After graduation from college, I worked on immune-diagnosis and on the epidemiology of schistosomiasis in the Jiangxi Parasitic Institute.

1990-1994 Dept. Endemic Diseases, Ministry of Health (MOH), Research Officer
I was in charge of the management of World Bank Loan Project on schistosomiasis control in China. At the beginning of the project I participated in designing and modifying the general strategy. In the implementation phase of the project, I was responsible for disease surveillance and information management as well as concurrently secretary of the TDR/MOH Joint Research Management Committee (JRMC).

1995-1996 Training in the Swiss Tropical Institute, Basel on Health Care and Management in Tropical Countries (HCMTC), Travellers' Health and Epidemiology supported by a stipend of Canton of Basel-Stadt.

1995 One month field studies on the epidemiology of schistosomiasis in Tanzania

1996-1999 Dept. Epidemiology, Institute of Parasitic Diseases, Shanghai, Associate Professor

2000-2002 Dept. Epidemiology, Institute of Parasitic Diseases, Shanghai, Senior Scientist

Since 1996, I have completed two projects supported by MOH. First, is a study on compliance by comparing two strategies of mass and selective chemotherapy in high endemic areas. Second, is a comparison of the strategies of "passive chemotherapy" and "active chemotherapy". The results indicate that active chemotherapy should replace passive chemotherapy during the consolidation period. Two major reports were finished: a medium term report on the evaluation of the schistosomiasis control project in China, and the final report of JRMC. At present, I have finished six projects. (1) Application of Remote Sensing in the Poyang Lake area in order to establish a transmission model for the prediction of high risk areas. (2) role of bovines in transmission in the lake area, (3) Asia network on schistosomiasis control, (4) an evaluation indicators system in China. (5) a final report of WB Loan project on schistosomiasis. (6) Morbidity control on schistosomiasis in China.

In 1997, I was selected as a member of Expert Consult Committee on Schistosomiasis, MOH. 1998 as a secretary in this committee.

2002-present Head of Dept. Schistosomiasis, National Institute of Parasitic Diseases, China Centre for Disease Control and Prevention. Responsibility for three major projects.

- Role of bovines in transmission in the lake areas, supported by NIH, US
- Environmental change impacting on control and transmission of *S. japonicum*, supported by NIH, US
- Surveillance of the impacted environmental change on schistosomiasis transmission in Yangtze River, supported by Chinese Government.

Membership of Professional Bodies:

- Secretary (Member) of Expert Consult Committee of Schistosomiasis, MOH of China, 1997 to present.
- Secretary of Joint Research Management Committee (JRMC), TDR&MOH, 1992 to 2001.
- Member of Editor of Chinese Journal of Schistosomiasis Control, 1999 to present

Special Fields of Experience

- Project Manager
- Planning, monitoring and evaluation
- Operational research on schistosomiasis control
- Geographic Information System (GIS) and Remote Sensing (RS)

Consulting experience:

1990	Integration of Schistosomiasis control during 8th Five-Years Plan
1991	Strategy of schistosomiasis control component of infectious and endemic diseases control project through the World Bank Loan
1997	Mid-term evaluation for the schistosomiasis component
1998	Evaluation and forecast of schistosomiasis spread during the flooding
1998	Evaluation of operational research
1999	Joint Research Management Committee report
2000	Application of GIS/RS in schistosomiasis control
2001	Integration of schistosomiasis control during 10th Five-Year Plan, and morbidity control on schistosomiasis in China
2002	Final report of World Bank Loan Project on Schistosomiasis in China

Research experience:

1985	Study on IHA diagnosis schistosomiasis japonicum in the field
1992	Index system for schistosomiasis control project with computer
1994	Analysis on cost-effectiveness in the project on schistosomiasis control
1995	One month field studies on the epidemiology of schistosomiasis in Tanzania
1996	Study on compliance with the strategies of mass and selective chemotherapy
1997	Comparison of the roles of passive and active chemotherapy
1998	Application of Remote Sensing in Poyang Lake area in order to establish a transmission model for the prediction of high risk areas.
1998	Study on the role of bovine transmission in lake areas.
1999	Set up Asia network on schistosomiasis control
2000	Evaluation of World Bank Loan project on schistosomiasis control
2001	Morbidity control on schistosomiasis control in China

2002 Application of Remote Sensing model to surveillance of the impacted environmental change on schistosomiasis in Poyang lake and Three Gorges Dam areas.

2003 Environmental change impacting on control and transmission of *S. japonicum*,

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Guo Jiagang, Robert Bergquist, Marcel Tanner. Final Report of Joint Research Management Committee (JRMC) for operational research of the China infectious and endemic diseases control on schistosomiasis component. (WHO Document 1999)

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