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HOST SNAILS OF HUMAN SCHISTOSOMIASIS IN THE TAVETA AREA OF KENYA, EAST AFRICA[1]

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Abstract: The present study was carried out in the permanent water streams of Lumi River, Irrigation Furrow and Lake Jipe in the Taveta area, Coast Province, Kenya during the dry seasons of 1974 and 1975, and the experimental infection was made at laboratory in Japan.

Freshwater snails collected in the Taveta area were as follows: *Biomphalaria pfeifferi* (Krauss), *B. sudanica* (Martens), *Bulinus globosus* (Morelet), *B. tropicus* (Krauss), *B. forskalii* (Ehrenberg), *Lymnea natalensis* (Krauss), *Ceratophallus natalensis* (Krauss), *Segmentorbis angustus* (Jickeli), *Gyraulus costulatus* (Krauss), *Bellamya unicolor* (Olivier) and *Melanoides tuberculata* (Müller).

B. pfeifferi was commonly found in river and irrigation canal, whereas *B. sudanica* only in lake. Natural infection of *Schistosoma mansoni* was found in *B. pfeifferi*, but not in *B. sudanica*. Both the two species were experimentally proved to be suitable intermediate snail hosts of *S. mansoni*. Therefore it was indicated that *B. pfeifferi* is the host snail of *S. mansoni* in the endemic area along river and irrigation canal while *B. sudanica* is suspected of playing the role in the transmission of *S. mansoni* in lakeshore.

B. globosus was commonly found in irrigation canal. Around 10 per cent of the snails proved to be naturally infected with *S. haematobium* on the conditions that many snails occurred. This snail was also experimentally proved to be susceptible to *S. haematobium*. *B. forskalii* was widespread, but the snail density seemed to be low. *B. tropicus* is well known as the not-intermediate snail host of *S. haematobium*. Therefore there might be a possibility to contribute only by *B. globosus* to the transmission of *S. haematobium* in this area.

INTRODUCTION

Schistosoma mansoni and *S. haematobium* are endemic in the Taveta area of Kenya located at the base of Mt. Kilimanjaro. Katamine *et al.* (1978) studied in detail the prevalence of schistosomiasis in some villages in this area and demonstrated that there

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are a village where *S. mansoni* is highly endemic, two villages where *S. haematobium* is highly endemic, a village where both the two schistosomes are endemic and a village where schistosome infection is rare. The same authors suggested that the fact mentioned above would be mainly influenced by the distribution of host snails of schistosomiasis in this area.

Up to the present the species and distribution of freshwater snails in Kenya and adjacent territory have been reported by Mozley (1939), Teesdale (1954), Mandahl-Barth (1954, 1962) and Brown (1974), and the records of snail collections in the Taveta area were found in only two reports by Teesdale (1954) and Brown (1974, personal communication).

The work reported here was undertaken as a part of the research programme on the epidemiology of schistosomiasis in the Taveta area to clarify the distribution of host snails of schistosomiasis, and to establish their roles in existing transmission patterns in this area.

Water system in the Taveta area

The Taveta area is located 180 km inland from the east coast in Coast Province of Kenya just near the boundary of Tanzania. The climate is of periodically dry savanna with an average annual precipitation of 700 mm and the altitude is around 720 m above sea level. The room temperature at the laboratory frequently rose above 30 C in the daytime and sometimes fell below 20 C at night during the stay in this area.

The permanent water streams, which many inhabitants naturally use for their lives, may be conveniently divided into the following three sections:

1. Lumi River

This river is separated into the three not-joining courses of which the upper one runs from Mt. Kilimanjaro and soon goes underground, of which the middle one runs from north Chala to Timbila where it also goes underground, and of which the down one runs to Lake Jipe. The middle course originates from the big spring and the down one originates from Njoro Kubwa Spring, which is as far as a hundred meters from the end of the middle course and is ten times bigger than the former spring. Therefore the courses of Lumi River may be not directly connected in turn even during the rainy season. A part of numerous water from Njoro Kubwa Spring is supplied for Irrigation Furrow too.

2. Irrigation Furrow

Water source of this irrigation is the same as that of the down course of Lumi River mentioned above. It runs through Kivalwa up to Eldoro and Kitovo in order to supply water to sisal estate and to inhabitants. It gradually slows down and drys up at Eldoro and Kitovo.

3. Lake Jipe

Seasonal fluctuation of water level may be more than 200 cm. Main vege-

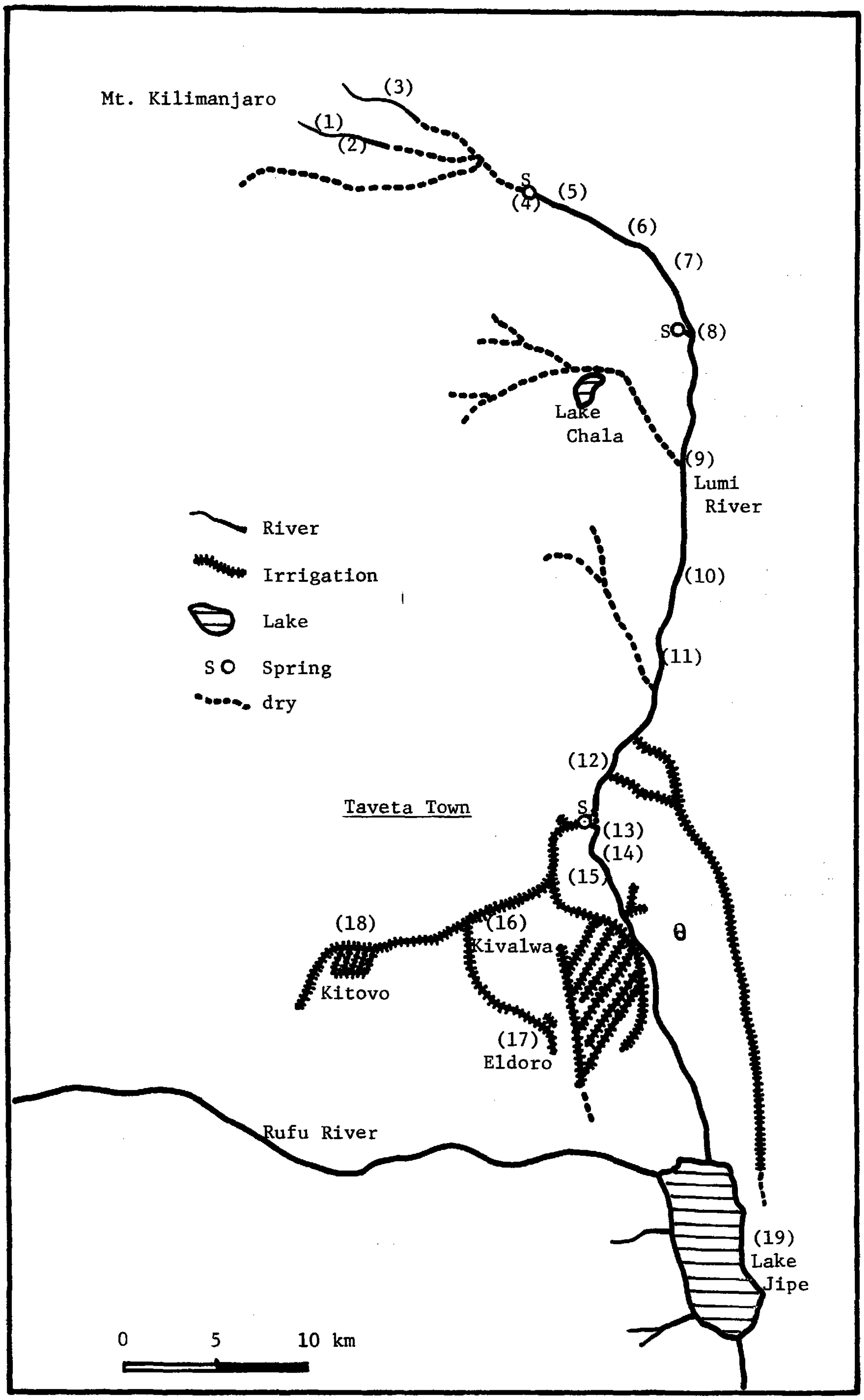

Figure 1 Water sources and courses in the Taveta area.
Nos. 1 to 19 correspond to points of snail surveys (Table 2)

tations of the lakeshore consist of around 10 m in width dried zone of rush and almost 50 m in width swamp zone of papyrus.

Materials and Methods

The present observations were made from September to December of 1974 and from August to November of 1975. A part of the experimental studies were done in Japan.

Snail collection: Snails were collected at random at 19 places in the permanent water streams of spring, Lumi River, Irrigation Furrow and Lake Jipe (Figure 1). Snail collection was made by hand or snail scoop. The surface temperature of water and other information were recorded when snails were collected. The typical snail samples were identified by Dr. D. S. Brown of British Medical Council, Kisumu in 1974.

Natural infection of snails with schistosome: The snails collected were brought to the laboratory and examined individually for schistosome infection in well water in small dishes (18 mm in diameter) which were placed for 5 hours under diffused sunlight. Identification of schistosome cercariae was difficult, because sufficient numbers of laboratory hamsters or mice were not available. Therefore, the limited numbers of hamsters or mice were exposed to schistosome cercariae pooled from some infected snails.

Experimental infection of snails with schistosome: *Biomphalaria pfeifferi* and *B. sudanica* used in the experimental infection were collected from the places where none of naturally infected snails with *S. mansoni* were found. They were examined by shedding method for schistosome infection at least 3 times at one week interval before use for experiment. *Bulinus globosus* used in the infection experiment was new offspring reared in laboratory. *B. tropicus* used was from Lake Jipe. The snails were exposed to different numbers of miracidia of *S. mansoni* and *S. haematobium* obtained from human infection, respectively. Each snail was kept in the small dish with 2 m*l* of water and miracidia for 5 hours. After the exposure of the snails to miracidia, they were maintained in the air-circulating water aqualium with mud-sand filter. The water temperature in an aqualium at laboratory in Taveta was 24–26 C in spite of around 10 C of variation in the room temperature in a day, whereas in Japan it was adjusted to 23–24 C or 25–26 C.

Results

1) Species and distribution of freshwater snails:

Species of freshwater snails collected are as follows; *Biomphalaria pfeifferi* (Krauss), *B. sudanica* (Martens), *Bulinus globosus* (Morelet), *B. tropicus* (Krauss), *B. forskalii* (Ehrenberg), *Lymnea natalensis* (Krauss), *Ceratophallus natalensis* (Krauss), *Segmentorbis angustus* (Jickeli), *Gyraulus costulatus* (Krauss), *Bellamya unicolor* (Olivier) and *Melanoides tuberculata* (Müller). Among them, *Biomphalaria* and *Bulinus* snails would be considered as the hosts of schistosomiasis. The distribution of these snails are shown in Table 1. *B. pfeifferi* was commonly found in many places such as 5–12, 16, 17 and 18, indicating that this snail occurs in Lumi River and in Irrigation Furrow, while *B. sudanica* occurs in Lake Jipe (19). *B. globosus* was commonly found in Irrigation Furrow (16, 17, 18) and *B. tropicus* occurs in both irrigation (17) and lake (19). Although *B. forskalii* was widespread, the number of snails collected was rather small in any places (5, 17, 19) (Figure 1, Tables 1 and 2).

Table 1 Freshwater snails in the Taveta area

Snail Species	River (Lumi)	Irrigation (Kivalwa, Eldoro, Kitovo)	Lake (Jipe)
Biomphalaria pfeifferi (Krauss)	++	+++	0
B. sudanica (Martens)	0	0	+++
Bulinus globosus (Morelet)	0	+++	0
B. tropicus (Krauss)	0	+	++
B. forskalii (Ehrenberg)	+	+	+
Lymnea natalensis (Krauss)	+	++	++
Ceratophallus natalensis (Krauss)	0	+	++++
Segmentorbis angustus (Jickeli)	0	0	+
Gyraulus costulatus (Krauss)	0	+	0
Bellamya unicolor (Olivier)	0	0	++
Melanoides tuberculata (Müller)	+	+	++

found *not* (0), *sometimes* (+), *easily* (++) and *commonly* (+++)

2) Natural infection of *Biomphalaria* snails with schistosome:

Results of the investigations are summarized in Table 2. Fourteen out of 238 *B. pfeifferi* from Lumi River (Timbila, 11) were proved to be naturally infected with mammalian schistosome cercariae which were identified as *S. mansoni* by infection experiment in mice. However, all *B. pfeifferi* collected from any other places of Lumi River were negative for schistosome. One out of 1,505 *B. pfeifferi* from irrigation (Eldoro, 17) was also proved to be naturally infected with *S. mansoni*. Although *B. sudanica* was wide-spread in papyrus swamp along the lakeshore of Lake Jipe, all showed negative results for schistosome.

3) Natural infection of *Bulinus* snails with schistosome:

Results of the investigation are also summarized in Table 2. In different places of Irrigation Furrow such as Kivalwa (16), Eldoro (17) and Kitovo (18), *B. globosus* proved to be naturally infected with mammalian schistosome cercariae, some of which were all identified as *S. haematobium* by exposing laboratory hamsters and mice. The positive rates in this snail showed 8.0 per cent in Kivalwa (16), 12.0 per cent in Eldoro (17), and 4.7 per cent in 1974 and 14.4 per cent in 1975 in Kitovo (18), respectively. Around 10 per cent of snails were positive for *S. haematobium* on conditions that many *B. globosus* snails occurred. *B. forskalii* and *B. tropicus* were not proved to be naturally infected with schistosome.

Table 2 Local distribution and natural infection of *Biomphalaria* and *Bulinus* snails in the Taveta area

Locality	Tem.	Snail species	No. exam.	No. (%) infected with *Schisto.*	Other trematoda
Lumi river					
Upper course					
(1), (2), (3)	22–24 C	no snail			
Middle course					
(4) Chala big spring	18 C	no snail			
(5)	18.5 C	B. p.	50	0	0
		B. f.	43	0	0
(6)	22.0 C	B. p.	90	0	0
(7)	23.0 C	〃	10	0	0
(8) Chala small spring	24.0 C	〃	19	0	0
(9)	24.5 C	〃	14	0	0
(10)	26.0 C	〃	37	0	0
(11) Timbila	26.5 C	〃	238	14 (5.9)	0
(12)	27.0 C	〃	20	0	0
Lower course					
(13), (14), (15)	22–24 C	no snail			
Irrigation Furrow					
Kivalwa					
(16)	22–24 C	B. p.	15*	0	3 (20.0)
		〃	2	0	0
		B. g.	562*	45 (8.0)	48 (8.5)
		〃	4	0	0
Eldoro					
(17)	28–29 C	B. p.	56*	0	1 (1.8)
		〃	1,505	1 (0.1)	181 (12.0)
		B. g.	75*	9 (12.0)	0
		〃	4	0	0
		B. f.	59*	0	0
		B. t.	59*	0	1 (1.7)
		〃	33	0	0
Kitovo					
(18)	28–29 C	B. p.	43*	0	4 (9.3)
		〃	227	0	11 (4.8)
		B. g.	43*	2 (4.7)	1 (2.3)
		〃	605	87 (14.4)	1 (0.2)
Lake Jipe					
(19) Kilometa-Saba	26–28 C	B. s.	131*	0	3 (2.3)
		〃	422	0	7 (1.7)
		B. f.	1	0	0
		B. t.	41*	0	6 (14.6)
		〃	48	0	0

B. p.: *Biomphalaria pfeifferi*   * 1974
B. s.: *B. sudanica*
B. g.: *Bulinus globosus*
B. t.: *B. tropicus*
B. f.: *B. forskalii*

4) Experimental infection of *Biomphalaria* snails with *S. mansoni*:

Results of the experiments are shown in Tables 3 and 4. In the experimental exposure of *B. pfeifferi* and *B. sudanica* to *S. mansoni* miracidia, both the two species of snails proved to be very susceptible to *S. mansoni*. The exposure of *B. pfeifferi* to a single miracidium showed 67 per cent in the positive rate, but the exposure of *B. sudanica* to the same dose showed negative result. The exposure of *B. pfeifferi* to 3 miracidia showed 100 per cent in the positive rate, and also the exposure of *B. sudanica* to 5 miracidia did 100 per cent. *S. mansoni* cercariae were recognized from *B. pfeifferi* 30–34 days after exposure and from *B. sudanica* 34–42 days at 24–26 C.

Table 3 Experimental infection of *B. pfeifferi* with different numbers of *S. mansoni* miracidia

No. of snails exposed	No. of miracidia per snail	No. (%) surviving 30–46 days	No. (%) positive	Cercarial incubation period (days)
10	1	6 (60)	4 (67)	32
9	3	6 (67)	6 (100)	30–32
8	5	4 (50)	4 (100)	30–32
20	5	18 (90)	18 (100)	1–34
9	10	5 (56)	5 (100)	32
10	20	7 (70)	7 (100)	32–34

Water temperature: 24–26 C

Table 4 Experimental infection of *B. sudanica* with different numbers of *S. mansoni* miracidia

No. of snails exposed	No. of miracidia per snail	No. (%) surviving 34–46 days	No. (%) positive	Cercarial incubation period (days)
10	1	7 (70)	0	—
10	3	6 (60)	4 (67)	34–42
9	5	6 (67)	6 (100)	34–40
10	10	4 (40)	4 (100)	36–42
10	20	7 (70)	7 (100)	36–40

Water temperature: 24–26 C

5) Experimental infection of *Bulinus* snails with *S. haematobium*:

Results of the experiments are shown in Table 5. In the experimental exposure of *B. globosus* and *B. tropicus* to *S. haematobium*, the former proved to be susceptible, but the latter showed negative for infection. The exposure of adult *B. globosus* (11–12 mm shell height) to a single miracidium showed negative result, but 10, 30 and 40 per cent of the adult snails were able to be infected when they were exposed to 3, 5 and 10 miracidia respectively. It seems that at least 20 miracidia are needed to infect all of adult *B. globosus*. On the other hand, the exposure of young *B. globosus* (2.5–8.5 mm shell height) to 5 miracidia showed 100 per cent in the positive rate. *S. haematobium* cercariae were recognized 88–93 days after exposure at 23–24 C, and 44–48 days at 25–26 C.

Table 5 Experimental infection of *Bulinus* snail with *S. haematobium*

Snail species (size)	No. of snails exposed	No. of miracidia per snail	Temp.	No. (%) surviving 44–126 days	No. (%) positive	Cercarial incubation period (days)
	10	1	23–24 C	9 (90)	0 (0)	
B. globosus	10	3		10 (100)	1 (10)	89
(11–12 mm	10	5		10 (100)	3 (30)	86
shell height)	10	10		10 (100)	4 (40)	88–93
	10	20*	25–26 C	9 (90)	9 (100)	44–48
B. globosus (2.5–8.5 mm)	33	5*	25–26 C	26 (79)	26 (100)	44–46
B. globosus (11.5–14.5 mm)	22	5*		17 (77)	4 (24)	44–48
B. tropicus	26	10–20	24–26 C	18 (69)	0 (0)	

*: Miracidia were hatched from feces of infected hamster with *S. haematobium* originating human infection.

Discussion

It was impossible in this study to make quantitative observations on the snail population and schistosome infection rates of the snails in any water streams, because of random surveys during a short period. However this study indicates the possible transmission pattern of schistosomiasis in waters in the Taveta area.

It is quite natural and well known that water connection directly influences the spread, distribution and redistribution of host snail of schistosomiasis. The permanent water streams in the Taveta area would be classified into the following sections due to water connection; the upper course of Lumi River, the middle course of Lumi River, the down course of Lumi River, Irrigation Furrow, and Lake Jipe. No host snail was collected in any place surveyed of the upper course of Lumi River (1, 2, 3 in Figure 1 and Table 2) and the down course of Lumi River (13, 14, 15). In the down course of Lumi River, plenty and rapid water stream refuses snail habitat. In the upper course, there is a temporary increase of water stream during the rainy season, but water conditions would not be unfavorable for snail habitat during the dry season. On the other hand, host snails were collected in 12 places of the middle course of Lumi River, Irrigation Furrow and Lake Jipe where are stagnant waters. The snails are able to grow up and reproduce in places such as stagnant waters, and would be widely redistributed from there.

In general, irrigation is typical permanent water stream and the use of irrigation to expand agricultural productivity is likely to increase the prevalence and incidence of schistosomiasis. Webbe (1963) concluded that the snails do not thrive well in well maintained irrigation canals, but that conditions encountered in many irrigation schemes, including low-gradient canal systems with slit and vegetation, unsatisfactory water management schedules employed for conveyance systems, poor drainage channels with night storage dams and temporary pools, provide suitable habitats for the snails. Irrigation Furrow in the Taveta area quite coincides in such conditions. Recently Choudhy (1975) also claimed the risk of irrigation for the prevalence and incidence of schistosomiasis in Kenya as have been reported by many workers (Sturrock, 1965, 1966; Webbe, 1963; Webbe and Jordan, 1966; McCullough *et al.*, 1968; Highton, 1974) in East Africa.

Much information has not been given about natural infection rates of *Biomphalaria* snails, because naturally infected snails were rarely found in the field. A few workers including Gordon *et al.* (1934) and Teesdale (1962) reported 0 to 30 per cent (usually around 3% or low) in natural infection rates of *B. pfeifferi* with *S. mansoni*. Prentice (1970) concluded that it was very difficult to find naturally infected *B. sudanica* (none out of 245,000), but exceptionally Magendantz (1972) reported relative high infection rates (0.5 to 7.7%, average 1.6%) in the same Lake Victoria. In the present study, 5.9 per cent of *B. pfeifferi* collected from Lumi River (Timbila ,11) and 0.1 per cent of the same snail from Irrigation Furrow (Eldoro, 17) proved to be naturally infected with *S. mansoni*, whereas, naturally infected *B. sudanica* failed to be found out in Lake Jipe.

Most workers have found out naturally infected *B. globosus*, and some workers including Blacklock and Thompson (1924), Hira and Muller (1966) and Paperna (1968) reported that natural infection rate was relatively high (mostly higher than 5%) and it temporarily rose nearly 50 per cent. In this study, around 10 per cent of *B. globosus* from Irrigation Furrow proved to be naturally infected with *S. haematobium* on the conditions that many snails occurred. A rise in percentage of *B. globosus* infected with *S. haematobium* as the snail density increases was also recognized in Irrigation Furrow. This fact was already reported by Teesdale and Nelson (1958), Webbe (1962) and Hira and Muller (1966).

Up to the present, natural infection of *B. forskalii* with *S. haematobium* has never been found in the field, in spite of numerous snail surveys previously reported. In this study, none out of 103 *B. forskalii* was infected with *S. haematobium*.

The relationships between the number of miracidia exposed to snail and the infection rate have been reported by many earlier workers. In the experimental infection of *B. pfeifferi*, 60 to 100 per cent of the snails were infected with *S. mansoni* when the snail was exposed to 10 miracidia (Cridland, 1955), and when the snail was exposed to 3 miracidia (Prentice *et al.*, 1970). In the experimental infection of *B. sudanica*, 52 per cent of the snails were infected with *S. mansoni* when the snail was exposed to 8 miracidia (McClelland, 1962), and 16 and 41 per cent of the snails were infected when exposed to 3 and 10 miracidia respectively (Prentice, 1970). In the present study, the exposure of *B. pfeifferi* to 3 miracidia of *S. mansoni* and the exposure of *B. sudanica* to 5 miracidia showed 100 per cent in the positive rate. The exposure of *B. pfeifferi* to a single miracidium showed highly 67 per cent in infection rate, whereas the exposure of *B. sudanica* to the same dose showed negative result. These experimental infection rates obtained in this study seem to be higher than the results in the previous papers mentioned above.

As regards to the age resistance of host snails to schistosomes, Archibald and Marshall (1932) noticed that young *B. truncatus* was more susceptible to *S. haematobium* than the adult snail. And Moore *et al.* (1953), Chu *et al.* (1966a), Sturrock (1967) and Lo (1972) recongnized this phenomenon in their experimental studies of *B. truncatus, B. truncatus, B. nasutus productus* and *B. guernei,* respectively. Webbe and James (1972) got 47.1, 55.8 and 96.0 per cent of high infection rates in the experimental infections of young *B. globosus* (4–5 week age, 5–6 mm) with 1, 3 and 7 miracidia of *S. haematobium,* respectively. In this study, the exposure of young *B. globosus* (2.5–8.5 mm) to 5 miracidia showed 100 per cent in the infection rate, but at least 20 miracidia were needed to infect all of adult *B. globosus* snails. In the exposure of *Bulinus* snail to different numbers of miracidia, it has been reported that an increase in infection rate occurred as the snails were exposed to an increasing number of miracidia (McClelland, 1965; Chu *et al.*, 1966b; Lo, 1972; Webbe and James, 1972). In this study. the exposure of adult *B. globosus* (11–12 mm) to 1, 3, 5, 10 and 20 miracidia showed 0, 10, 30, 40 and 100 per cent in infection rate respectively. Infection rate of *B. globosus* increased with numbers of miracidia of *S. haematobium.*

B. pfeifferi was found to be naturally infected with *S. mansoni* in the middle course of Lumi River and in Irrigation Furrow, and this snail was easily infected experimentally. This fact seems to show that the transmission of *S. mansoni* may take place in some places of the middle course of Lumi River and of Irrigation Furrow. No naturally infected *B. sudanica* with *S. mansoni* was found from the field in Lake Jipe, but the snail was proved to be susceptible to *S. mansoni* originating human infection. Papyrus swamp of Lake Jipe was the main habitat of *B. sudanica.* Therefore, it would be suggested that the transmission of *S. mansoni* by *B. sudanica* takes place there in Lake Jipe.

B. globosus was found to be naturally infected with *S. haematobium* in Irrigation Furrow, and this snail was easily infected experimentally, especially when the snail was young. This fact seems to show that the transmission of *S. haematobium* takes place in any place of Irrigation Furrow. *B. forskalii* was widespread, but the snail density seems to be low. *B. tropicus* is well known as the not-intermediate snail host of *S. haematobium.* Therefore, there might be a possibility to contribute only by *B. globosus* to the transmission of *S. haematobium.*

It was concluded that *Biomphalaria pfeifferi, B. sudanica* and *Bulinus globosus* are the most important species in the transmission of schistosomiasis in the Taveta area.

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東アフリカ・ケニア，タベタ地区における住血吸虫症の媒介貝類について[1]

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ケニア国タベタ地区での淡水産貝類は以下の8属11種である。即ち *Biomphalaria pfeifferi*

1 ケニアにおける住血吸虫症の研究（第2報）　本研究は長崎大学熱帯医学研究所に対する文部省特別事業費により行われた。2 鹿児島大学医学部医動物学教室　3 長崎大学熱帯医学研究所寄生虫学部門　4 九州大学医療技術短期大学部医動物学研究室

(Krauss), *B. sudanica* (Martens), *Bulinus globosus* (Morelet), *B. tropicus* (Krauss), *B. forskalii* (Ehrenberg), 以上５種は住血吸虫との関係種, *Lymnea natalensis* (Krauss), *Ceratophallus natalensis* (Krauss), *Segmentorbis angustus* (Jickeli), *Gyraulus costulatus* (Krauss), *Bellamya unicolor* (Olivier) *Melanoides tuberculata* (Müller) である。

B. pfeifferi は Lumi 川と灌漑用溝に, *B. sudanica* は Jipe 湖畔に, それぞれの多数の棲息をみたが, マンソン住血吸虫の自然感染は *B. pfeifferi* のみに見られた。*B. globosus* は灌漑用溝のみに多数棲息し, *B. tropicus* は灌漑用溝と Jipe 湖畔に, *B. forskalii* は少数ながらあらゆる水系に見出された。ビルハルツ住血吸虫の自然感染は *B. globosus* のみに見出され, その貝の棲息数が多いと約10%の高い感染率が常時認められた。

一方これらの実験感染では, *B. pfeifferi* には３隻のミラシジウムで, *B. sudanica* には５隻のそれで100%感染が成立し, 両種ともマンソン住血吸虫の好適な中間宿主であることがわかった。

B. globosus は 1.5〜8.5 mm の若い貝は５隻のミラシジウムで100%感染が成立し, 11〜12 mm の成貝では20隻以上のミラシジウムが必要である。ビルハルツ住血吸虫の好適な中間宿主であることがわかった。

以上からタベタ地区でのマンソン住血吸虫症, ビルハルツ住血吸虫症の媒介中間宿主として, 前者には *B. pfeifferi* と *B. sudanica* が, 後者には *B. globosus* が主な役割を演じていることが推測される。