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## *Full Length Research Article*

# THE GROWTH, REPRODUCTION AND SURVIVAL OF *BIOMPHALARIA* SPECIES IN THE FIELD AND LABORATORY CONDITIONS AT LAKE ALBERT IN WESTERN UGANDA

**[1,*]Francis Kazibwe and [2]Edward Ssemakula**

[1]Associate Professor of Public Health at Bishop Stuart University, Uganda
[2]Graduate School at Bishop Stuart University (BSU), Mbarara Uganda

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**ABSTRACT**

Bilharzia or Schistosomiasis is a parasitic infection of man and is caused by blood flukes of the genus Schistosoma. The parasite is transmitted through specific aquatic intermediate hosts in various freshwater habitats. In terms of socioeconomic and public health importance it is regarded second to malaria among the parasitic diseases affecting man in tropical and some sub-tropical countries of the world. To understand the disease transmission patterns better; a study was carried out on the population dynamics of the snail types (Biomphalaria species) that are responsible for the transmission of the disease. This paper discusses the results of the study that was carried out at Lake Albert, which is one of the most affected areas by Bilharzia disease in the country. The growth, reproduction and survival of two Biomphalaria species at Lake Albert were monitored in the field and laboratory for thirteen and fourteen weeks respectively. Field and laboratory growth curves were constructed for the two Biomphalaria species, Biomphalaria stanleyi and Biomphalaria sudanica. The snails from the natural environment for both species showed a rapid and steady increase in size until they reached maximum growth at about the fourteenth week. As the snails matured, maximum egg production capacity was achieved from the tenth week onwards. The growth of snails in the laboratory was much slower especially for B. sudanica, and the snails never attained the shell diameter levels of the snails in the natural environment within the same period. It took an extra week for snails in the laboratory to reach maturity and to start egg production. By the end of the fourteenth week, the laboratory snails did not appear to have achieved a level of maximum egg production. There was a negative correlation between the mean generation time and the intrinsic rate of natural increase. These observations stress the importance and requirement of optimum conditions in the habitat of snails for them to maintain their numbers. With global warming and the attendant floods, occurring in many areas of the tropics including Uganda, fertile ground for multiplication of the snails with eventual possibility of spread of bilharzia, can be a big threat. There is a need to be vigilant and identify possible resurgence in snail population that may lead to the spread of bilharzia.



## INTRODUCTION

*Biomphalaria stanleyi* and *Biomphalaria sudanica* were reported to be the intermediate hosts of *Schistosoma mansoni* at Lake Albert Kabatereine 2000. The two species were later observed to have great variation in their population densities in the lake (Kazibwe, 2004), unpublished observation. On the basis of growth curves, the two species were also observed to have different shell diameter measurements.

****Corresponding author: Francis Kazibwe,***
*Associate Professor of Public Health at Bishop Stuart University, Uganda.*

An epidemiological study of the two species was carried out to elucidate the differences between them in growth, reproduction and mortality rates. The environmental factors that could have an influence over these parameters were considered in another ecological study in the same area (Kazibwe *et al* 2006). In earlier studies, it was shown that information on the net reproductive rate of snails gave an idea of the nature of snail survival and reproduction rates in a particular habitat during a given time interval (Klumpp *et al* 1985). Positive snail population growth is indicated by a net reproductive rate value of more than one. It has been shown that if this value is exactly one or less the population is either static or declining (Shiff 1964, Webbe 1982).

The net reproductive rate in these studies was mainly based on different successive snail generations over time. This meant that the time taken from one generation to another was not constant as it would mainly be dictated by the prevailing environmental conditions in a habitat. Therefore, in snail ecological studies, caution was necessary when comparing the effects of different environmental parameters on growth (Shiff 1964, Webbe 1982). Schistosomiasis is a disease of public health significance whose impacts on our socio-economic fabric are not given due considerations by authorities in general and disease control personnel, in particular. This situation antagonizes the planning and the disease intervention efforts in many endemic areas of our country. The vectors of the disease, their biology and the circumstances leading to their vectorial potential and the interplay between the environmental conditions and disease transmission have not been adequately studied in Uganda to aid in disease and vector control efforts. This study is an initial effort to address the knowledge gap in those areas with an objective of understanding the growth, reproduction and survival of the vectors at Lake Albert by collecting data to plot field and laboratory growth curves in order to be able to plan for effective control measures in future. The study was meant to address the question on what the actual species involved in disease transmission, their location, seasonal density fluctuations and reproductive potential were. The study was also meant to throw light on the implication of snail population dynamics given the changing climatic conditions, resulting into flooding and water logging.

## Methods and materials

### Study area

The study was conducted at Lake Albert in Western Uganda and in the laboratory situated in Piida village of Butiaba Parish along the shores of the lake.

### Growth, reproduction and survival of snails in the natural habitat

Two sets of wooden cages were designed; one for shallow water and the other for deep water, to monitor growth, reproduction and survival of snails. Each cage set consisted of a large wooden outer frame with open sides, a base trough containing a 5 cm layer of sand and gravel to anchor the cages firmly in position against the strong winds and waves of Lake Albert; and a wooden top incorporating slots to hold three, small inner cages. These inner cages had wooden frames over which green nylon mesh was fixed to confine the snails while allowing free circulation of lake water. One side of each cage could be opened to add, remove or examine the snails. The shallow water outer cage measured 105 cm by 90 cm by 60 cm and the small inner cages measured 90 cm by 30 cm by 45 cm. The deep water outer cage measured 120 cm by 105 cm by 60 cm and the small inner cages measured 105 cm by 30 cm by 60 cm. During baseline trials, it was found that *Biomphalaria* species preferred to deposit their egg masses on free objects such as water plants like the Nile Cabbages (*Pistia* Sp.) or strips of polystyrene. Therefore, a piece of polystyrene measuring ten centimetres by five centimetres and two young *Pistia* plants were put in each small cage as suitable substrates for the snails to deposit their egg masses. One deep water cage was placed 500 meters away from the shoreline in Booma village. The site was sheltered from strong winds and wave action by reeds and sedges and had little interference from human activities. The shallow water cage was placed five meters from the shoreline in a well-sheltered site. This site also had no interference from humans and other animals. Both sites were shown to be free of any transmission of *S. mansoni* during baseline surveys the previous year. Before introducing the snails, the cages were left in their respective sites for two weeks to allow the growth of algae, to serve as snail food.

During the field trials, thirty laboratory bred snails of each *Biomphalaria* species were placed in the lake in each of the three small cages and labelled according to group size as small (1), medium (2) and large (3). All the cages were retrieved once a week from a canoe to measure the shell diameter of surviving snails. The numbers of surviving and dead snails were recorded separately. Dead snails were removed from the cages during each visit. The egg masses in each cage were collected and counted under a dissecting microscope. All eggs were then taken to laboratory tanks for hatching and rearing to provide a constant supply of experimental snails. Each snail generation in the cages was monitored for five weeks and then replaced with a new generation from laboratory stocks. Data on egg laying, growth, survival and mortality rates were used to plot growth curves for each *Biomphalaria* species.

### Growth, reproduction and survival of snails under laboratory conditions

The same experiments as above were performed in the laboratory using four litre plastic tanks instead of cages. Each size category was monitored in a separate tank placed on wooden racks in the laboratory. The tanks were moved around daily to randomise the effects of extraneous factors within the laboratory. A piece of Polystyrene and two young Nile Cabbage plants were also put in each tank. Similar procedures as with the field snails were carried out on the laboratory snails weekly and the data were also recorded in the same way. The water used in the laboratory tanks was drawn from the lake and left to stand in plastic containers for one week before use. The laboratory snails were fed on dry, scalded lettuce.

### Construction of life tables for *Biomphalaria* species

The data used to construct life tables for each *Biomphalaria* species were derived from the experiments on weekly shell diameter measurements of caged snails in the field and laboratory. The proportion of snails that survived during each week for each species was entered in the survival ($l_x$) column. The average number of eggs produced per snail during the same period was entered in the fecundity ($m_x$) column and the product of these two values entered in a third column ($l_xm_x$). The sum of the weekly $l_xm_x$ values $\Sigma(l_xm_x)$ represented the net reproductive rate ($R_o$). As in previous studies (Webbe 1962a Shiff 1964 Sturrock 1973b O'Keef 1985a, b), the intrinsic rate of natural increase, (r), was determined from $R_o$ iteratively (by trial and error substitution) using Slobodkin's theorem of stable age distribution (Slobodkin 1961) using the following formula: -

$\Sigma(l_x m_x).\ e^{-rx} = 1.0$ ..... [1]

where: -

x = time in weeks
$l_x$ = proportion of snails surviving to each successive week.
$m_x$ = average number of eggs produced per snail during each successive week
e = the base of natural logarithms, and
r = intrinsic rate of natural increase.

A template to facilitate the quick calculation of life table parameters based on the field and laboratory data was set up using an Excel computer programme. Briefly, each parameter was calculated in sequence as shown below: -

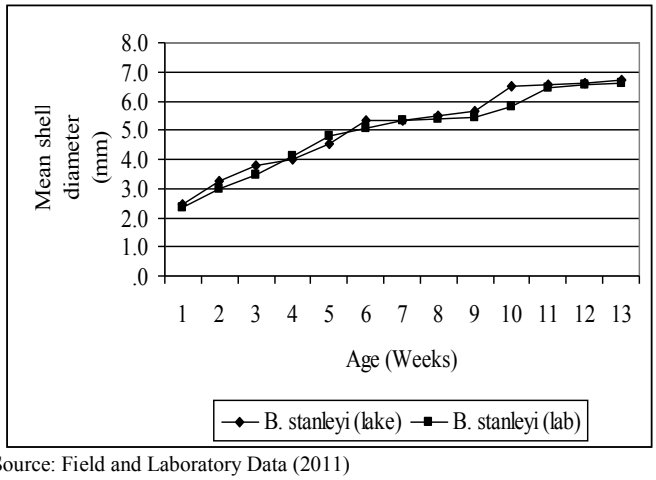
- The Net Reproductive Rate ($R_o$) = $\Sigma(l_x m_x)$.
- The Finite Rate of Population Increase (R) is the antilog of $Log_{10}$ R found by iterative substitution in equation [1] above,
- The Intrinsic Rate of Natural Increase (r) =$\log_e R$.
- The Mean Generation Time in weeks (MGT) = $\log_{10}R_o/\log_{10}R$.

The Net Reproductive Rate ($R_o$) was used to calculate the Finite Rate of Increase (R) from Equation [1] above. The Intrinsic Rate of Population Increase (r) is the natural logarithm of the value obtained for R. The mean generation time (MGT) in weeks for snail population growth is the ratio of the logarithms of Net Reproductive and Intrinsic Reproductive rates.

## RESULTS

### Growth of *B. stanleyi*

The field and laboratory growth curves for *B. stanleyi* are shown in figure 1. The growth of *B. stanleyi* in the natural environment and the laboratory was almost the same. By the thirteenth week, the snails had achieved a maximum mean shell diameter of close to 6.7mm.

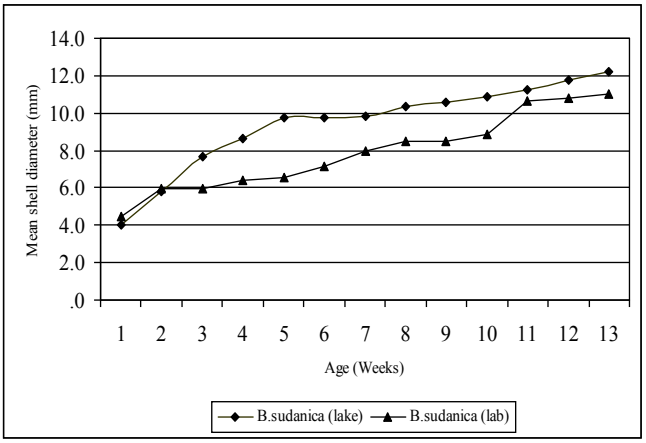



Source: Field and Laboratory Data (2011)

**Figure 1. Field and laboratory growth curves for *B. stanleyi* at Lake Albert**

### Growth of *B. sudanica*

The field and laboratory growth curves for *B. sudanica* are shown in figure 2. In the natural environment, snail growth was faster in the first five weeks. Thereafter, there was gradual growth until a maximum shell diameter of more than 12mm was achieved during the thirteenth week. The growth of laboratory snails was fast during the first two weeks followed by slow but steady growth. There was remarkably faster growth during the eleventh week. The laboratory snails never reached the shell diameter level achieved by the field snails within the same period.




Source: Field and Laboratory Data (2011)

**Figure 2. Field and laboratory Growth curves for *B. sudanica* at Lake Albert**

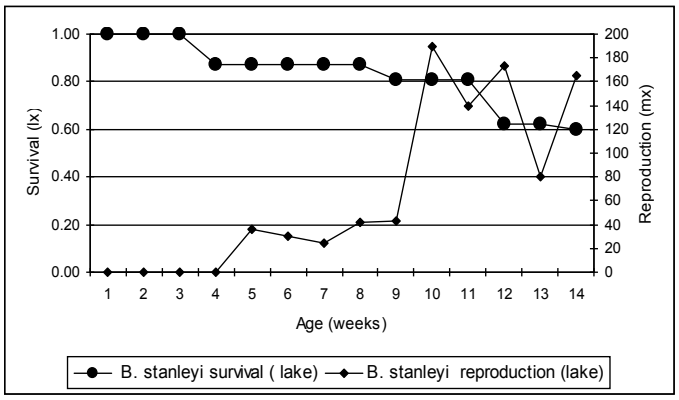
### The intrinsic rate of natural increase, finite rate of increase, net reproductive rate and the mean generation time of *Biomphalaria* species

A series of observations were made on *Biomphalaria* species to collect data on the intrinsic rate of natural increase (r), the finite rate of increase (R), the net reproductive rate (Ro) and the mean generation time (MGT). A correlation analysis was performed on the above growth parameters for each species to detect any significant differences between them. The strength of the correlations was further tested by fitting the regression coefficient ('r') in the model. The correlations between the intrinsic rate of natural increase and the finite rate of increase, and the finite rate of increase and the net reproductive rate for each species were strong ('r' = 0.886 and 0.876 respectively). The regression coefficient values for the intrinsic rate of natural increase and the mean generation time, and the finite rate of increase and the mean generation time ('r' = -0.622 and -0.602 respectively) were highly significant ($P < 0.001$). The lowest regression coefficient was for the correlation of mean generation time and net reproductive rate ('r' = -0.400).

### Survival and reproduction of *B. stanleyi* in the natural and laboratory environments

The survival rate of *B. stanleyi* in the lake was sustained at 100% during the first three weeks before noticeable mortality occurred between the third and fourth week (Figure 3). Survival remained constant from that time until the eighth week when another bout of mortality occurred between the eighth and ninth weeks.

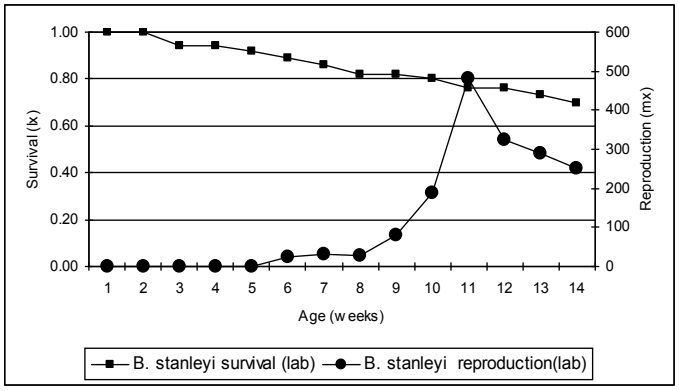
Snail survival thereafter remained constant until the eleventh week. Heaviest mortality was experienced during the twelfth week. However, survival remained constant at almost 60% thereafter up to the fifteenth week when the experiment was stopped. Egg production started in the fourth week with a mini peak during the fifth week. From the ninth week, there was a steady increase in egg production until a high peak was realized during the tenth week. The fecundity pattern from the tenth to the fifteenth week was directly proportional to the density of surviving snails.




Source: Field and Laboratory Data (2011)

**Figure 3. Survival and reproduction of *B. stanleyi* in the natural environment at Lake Albert**

The survival rate of *B. stanleyi* under laboratory conditions was 100% during the first two weeks (Figure 4). Thereafter the survival rate dropped quite slowly but never fell below 70%. Egg production started in the fifth week and the rate increased steadily to a single peak in the eleventh week. This was followed by a big decline until the fourteenth week.

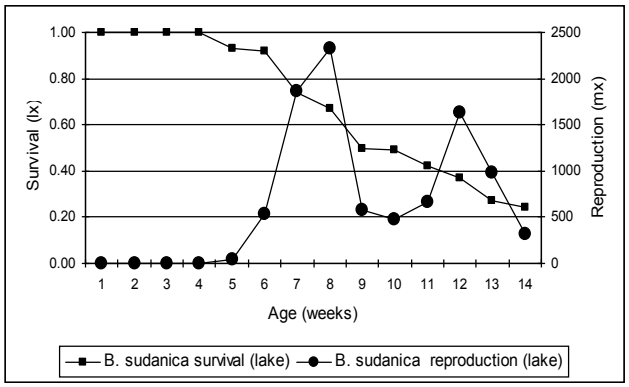



Source: Field and Laboratory Data (2011)

**Fig. 4. Survival and reproduction of *B. stanleyi* in the laboratory at Lake Albert**

### Survivorship and fecundity of *B. sudanica* in the natural and laboratory environments

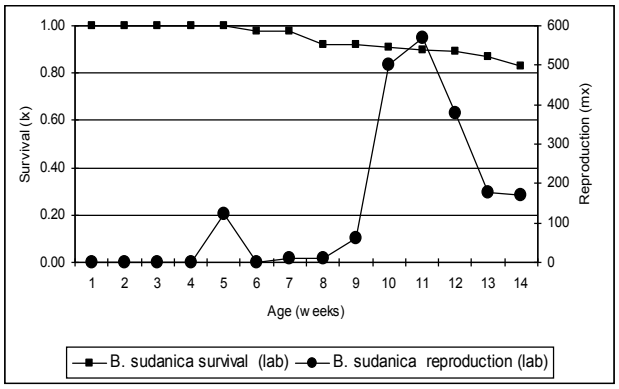
The survival of *B. sudanica* in the natural environment was different (Figure 5). There was no mortality in the first four weeks. However, by the end of the observation period only 22% of the original snails were still alive. Egg production started in the fifth week and reached a peak during the eighth week.




Source: Field and Laboratory Data (2011)

**Figure 5. Survival and reproduction of *B. sudanica* in the natural environment at Lake Albert**

Under laboratory conditions, *B. sudanica* showed a high survival rate of more than 90% during the first five weeks and 80% of the original snails were still alive by the 15th week (Figure 6). Egg production under laboratory conditions started in the fourth week with a peak in the eleventh week.




Source: Field and Laboratory Data (2011)

**Figure 6. Survival and reproduction of *B. sudanica* in the laboratory**

## DISCUSSION

The studies on snail population dynamics at Lake Albert showed a negative correlation between the mean generation time and the intrinsic rate of natural increase, the net reproductive rate and the finite rate of increase. This meant that as snail growth improved, the mean generation time diminished. The correlations between the intrinsic rate of natural increase, the finite rate of increase and the net reproductive rate, were all positive, that is the greater the value of one, the greater the value of the other. The eggs laid as the snails got older, often in quite large numbers, played a much larger part in determining the values of the net reproductive rate than in determining the finite rate of increase and the intrinsic rate of natural increase. This introduced a lot of variability in the net reproductive rate. Species with a high intrinsic rate of natural increase and short mean generation time are sometimes termed opportunistic or r-strategists. They are capable of repopulating habitats after catastrophic population declines following some natural disaster.

It matters not if they crash again when conditions deteriorate as long as a few snails can survive until favourable conditions return. Both species in the natural habitat had a shorter mean generation time than those in the laboratory. In the laboratory, snails also took longer to reach maturity and to start egg production. These findings agreed with those of Sturrock (1973) in his studies on the transmission of *Schistosoma mansoni* and on the bionomics of its intermediate host on St. Lucia in West Indies and O'Keef (1985a b) in his studies on the population biology of the freshwater snail *Bulinus globosus* on the Kenya coast. These results can be explained by the fact that natural environmental conditions are more conducive for snail proliferation than the more restricted conditions in the laboratory. There are many other factors which must be considered when explaining this difference. Rainfall is one of the important factors as it will bring from the land into a snail habitat nutrients and essential chemicals like calcium and magnesium which are vital for snail growth and shell formation (Williams 1970 Dussart 1976 McKillop 1985 McKillop and Harrison 1972).

Snail populations are also affected by variations in temperatures (Klumpp *et al* 1985). The study results point to the possible snail population growth and escalation during the erosive and flood prone rainfall and thunderstorms, which are characteristic of global warming. The resultant snail population dynamics calls for further investigations in order to stem dangers of bilharzias infection that may debilitate the communities causing negative effects in growth and development. Conditions found in a natural environment are extremely difficult to simulate in the laboratory, and therefore snail growth is invariably curtailed.

At the field laboratory at Lake Albert, it was most likely that competition for space in water tanks and food were major limitations on snail growth. It was observed both in the field and laboratory, that when conditions became less than optimum, there were high mortalities among the snails. This mortality affected the intrinsic rate of natural increase (r) especially for laboratory snail populations. The values for r were positive, though not very high, in the laboratory studies, showing that both species were capable of population growth in the prevailing (sub-optimal) conditions of the laboratory. In the more favorable field conditions, r values were even higher due to a combination of rapid growth, reasonable survival and high egg production which allowed both species the potential for rapid, almost explosive population growth.

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