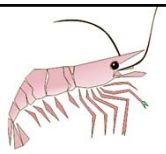

Aquaculture pur la Santé

Native Prawns: A Candidate New Tool for Schistosomiasis Control

LABORATORY, FIELD, AND MODELING STUDIES

Giulio De Leo, & Susanne Sokolow,
ICTP – Sao Paulo
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  - **Sam Loker** (University of New Mexico)
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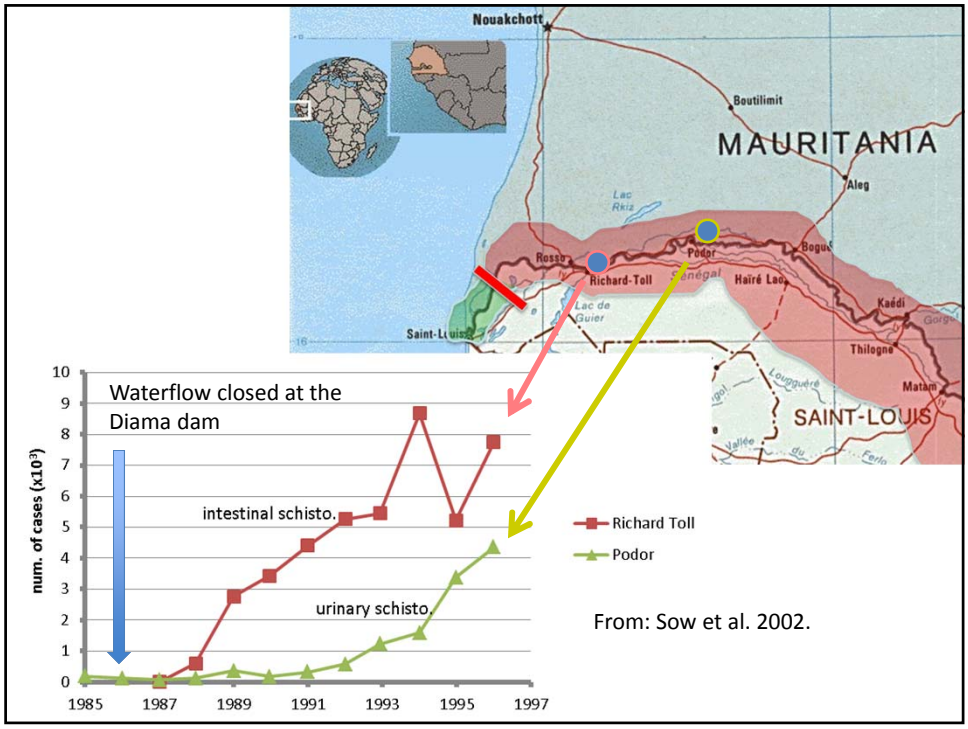
  - **Daniel Colley** (SCORE director, University of Georgia - external advisor)
  - Agence Nationale de l'Aquaculture (ANA) & Agency of Integration and Agricultural Development (Senegal)

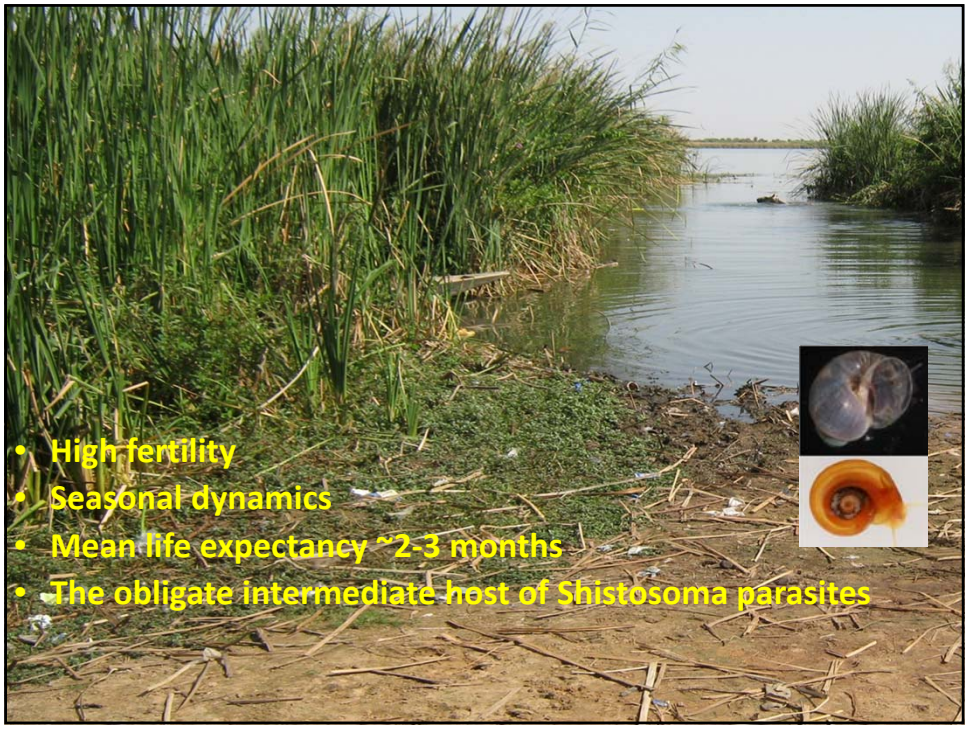
Sanna Sokolow, PhD in Disease Ecology
- Co-PI with Armand Kuris (UCSB) of the NIH-K08 project "Emergence and Biological Control of Schistosomiasis" NIH Grant # PHS K08AI082284, 2009-2012

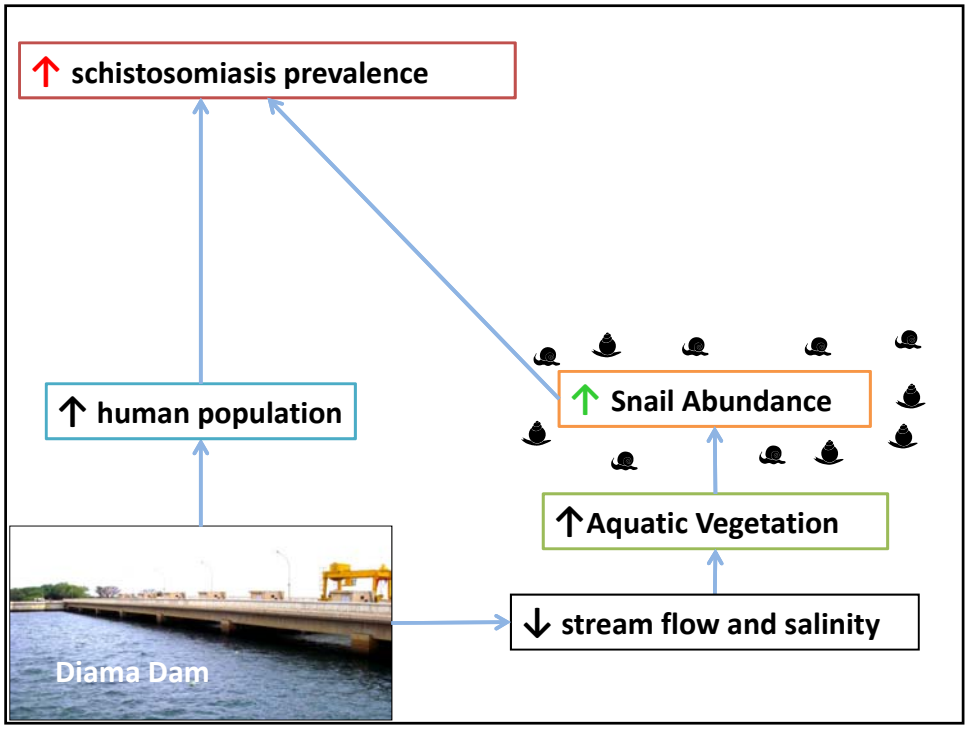
Stanford Woods Institute for the Environment

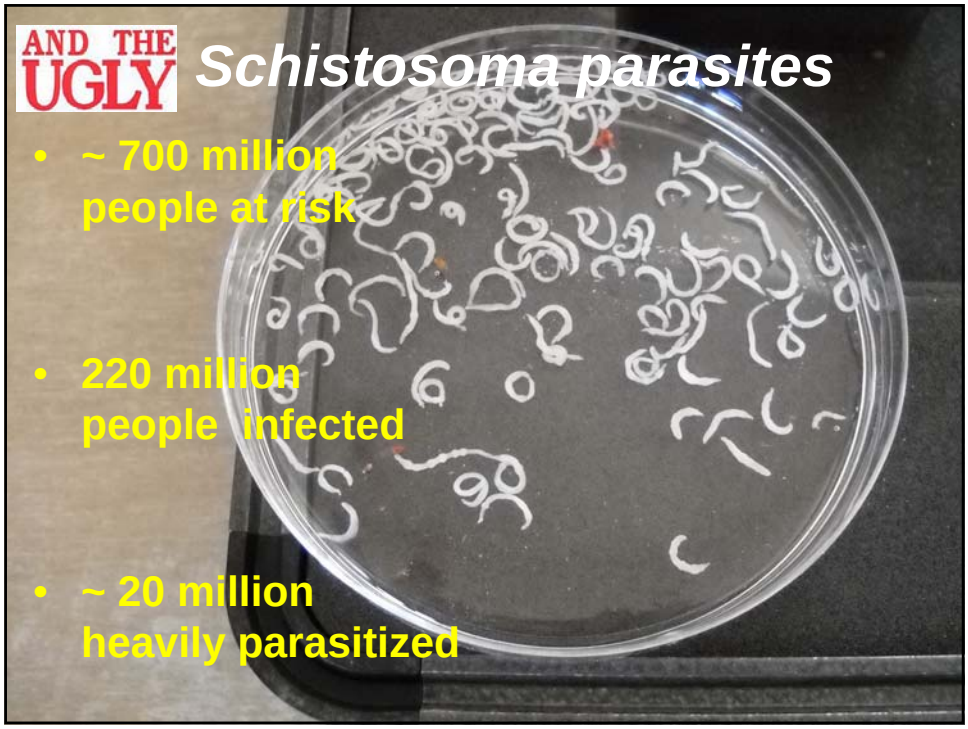
Senegal River Basin

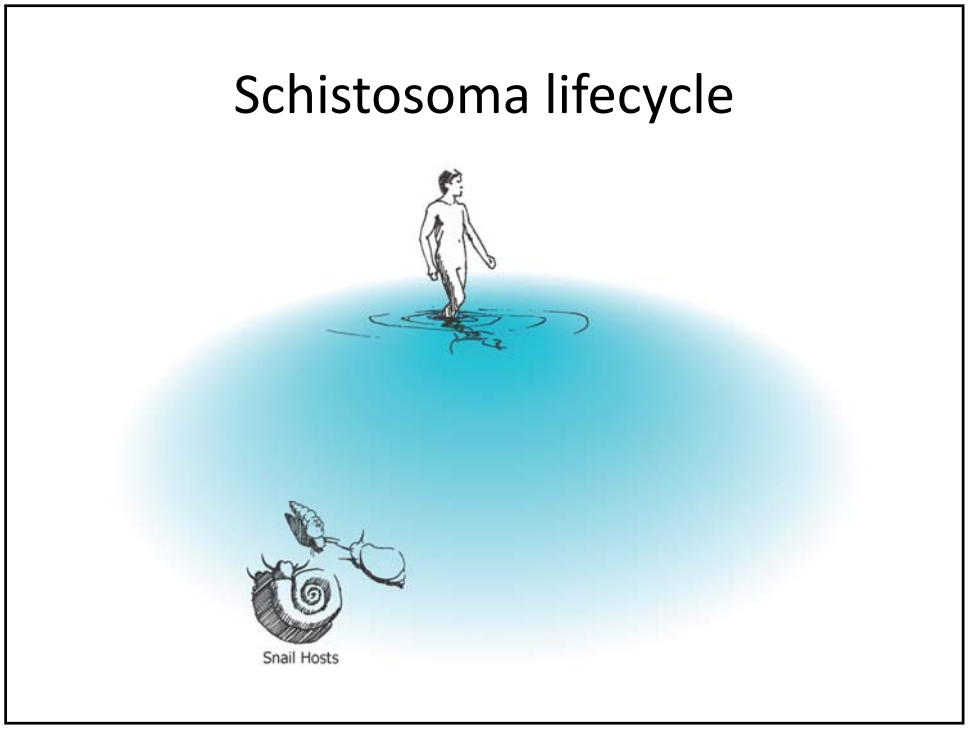
Diama Dam, Senegal



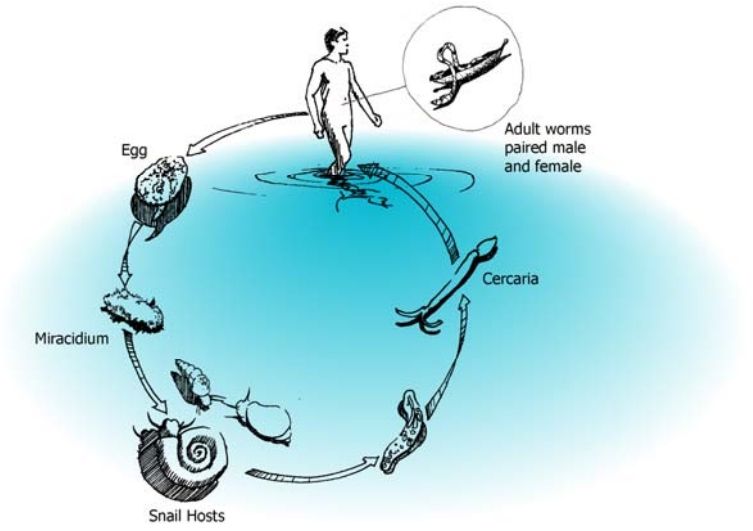








Schistosoma lifecycle



Pathology

- Chronic anemia
- Growth stunting
- Wasting
- Cognitive impairment
- Lack of physical fitness
- Genital lesions
  - Increased risk of HIV
- Infertility
- Liver failure
- Bladder cancer

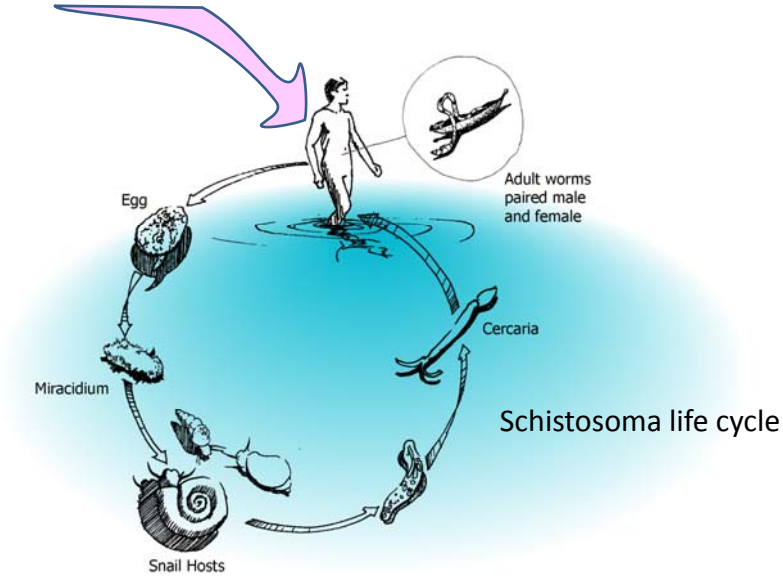
Treatment options and eradication strategies

- **A Success: USAID's Neglected Tropical Disease Program**

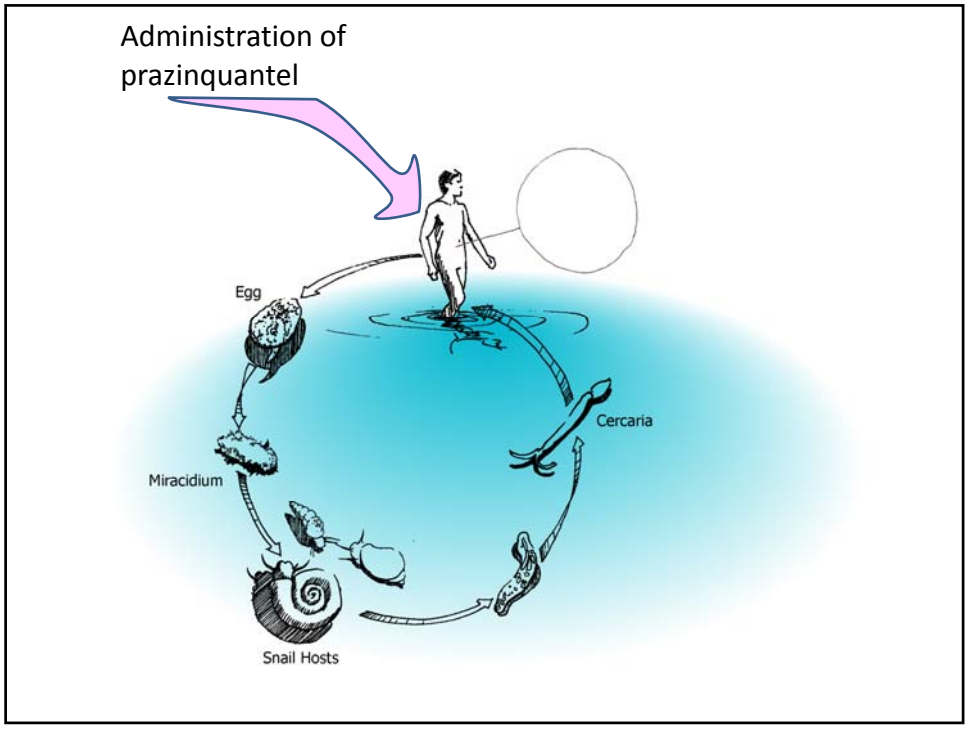
"nearly 16 million people [affected by Schistosomiasis] were treated [with praziquantel] during the first year…55 million people by the third year"

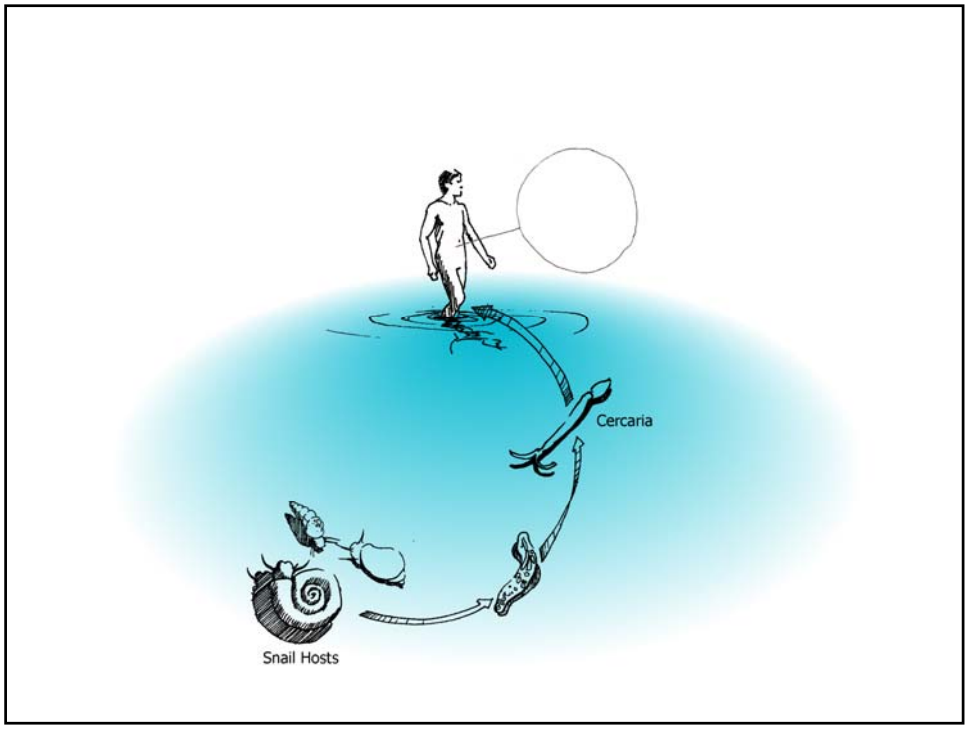
"major drug donors…totaled more than $1.4 billion…"

Administration of prazinquantel



Schistosoma life cycle

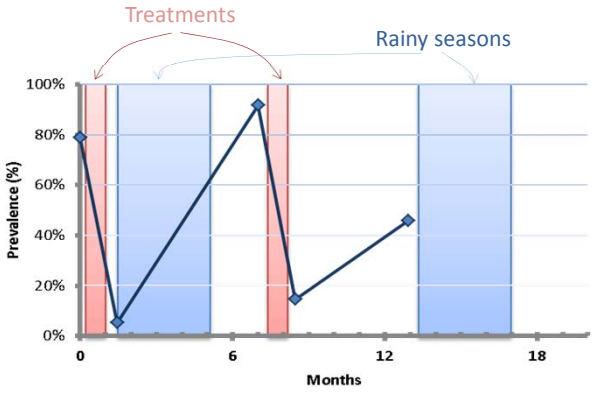


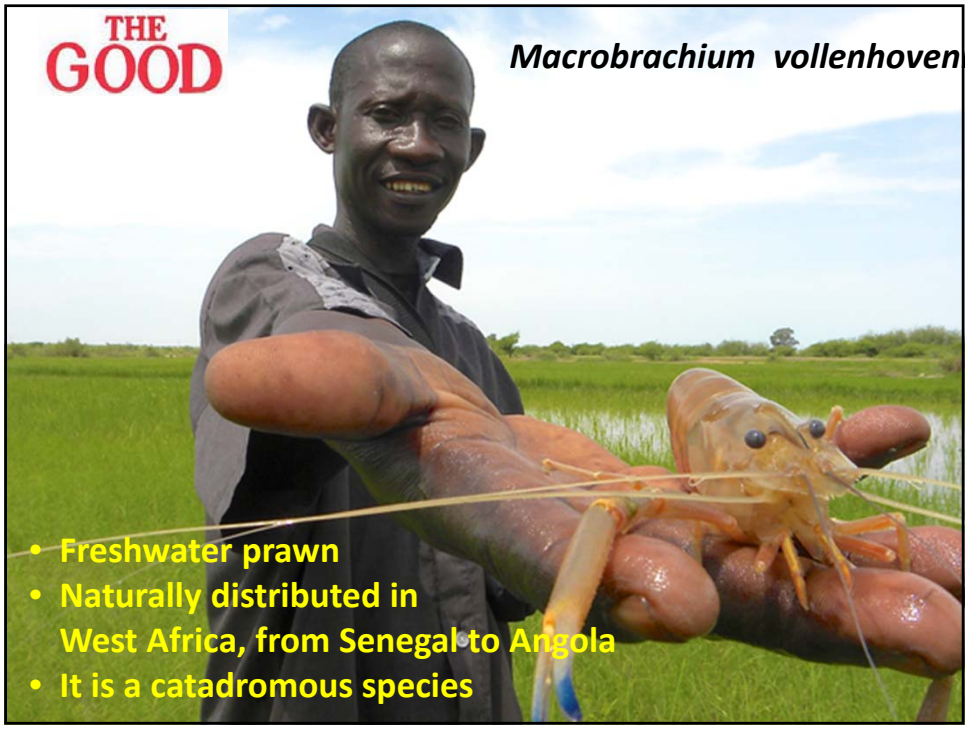


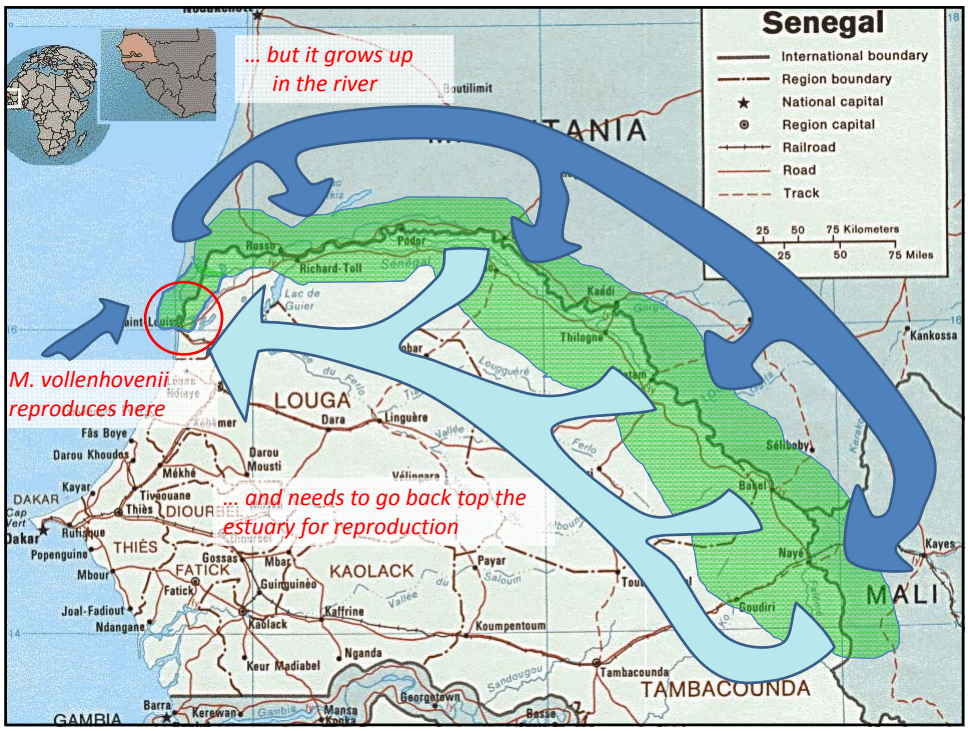
Transmission sites

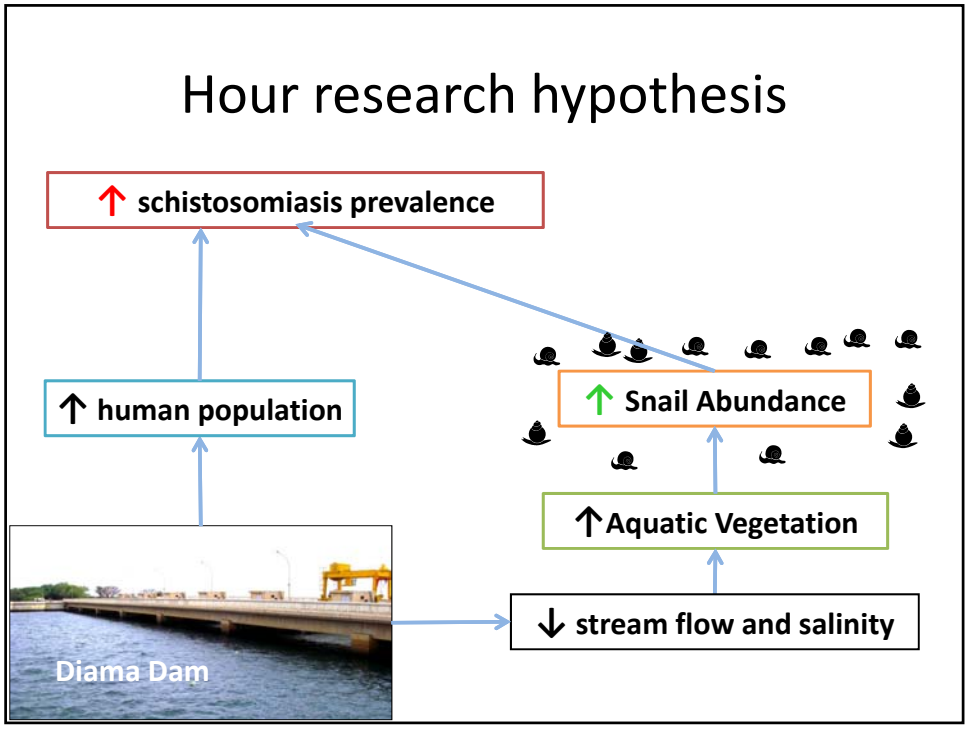
Reinfection patterns of schistosomiasis after treatment

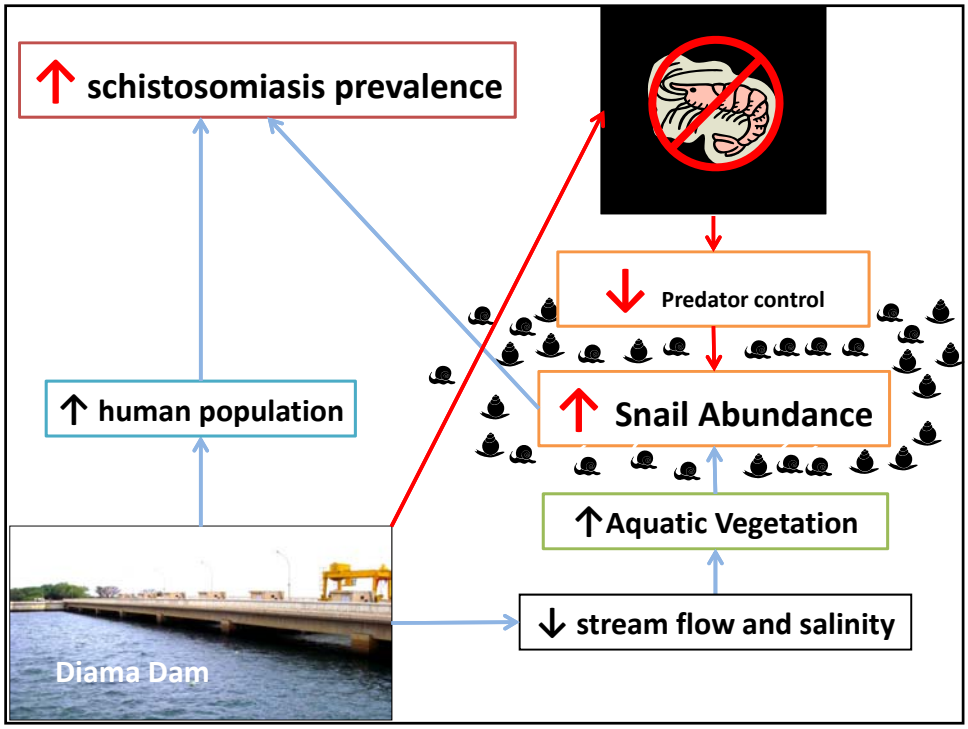
Webster et al 2013 *Acta tropica*

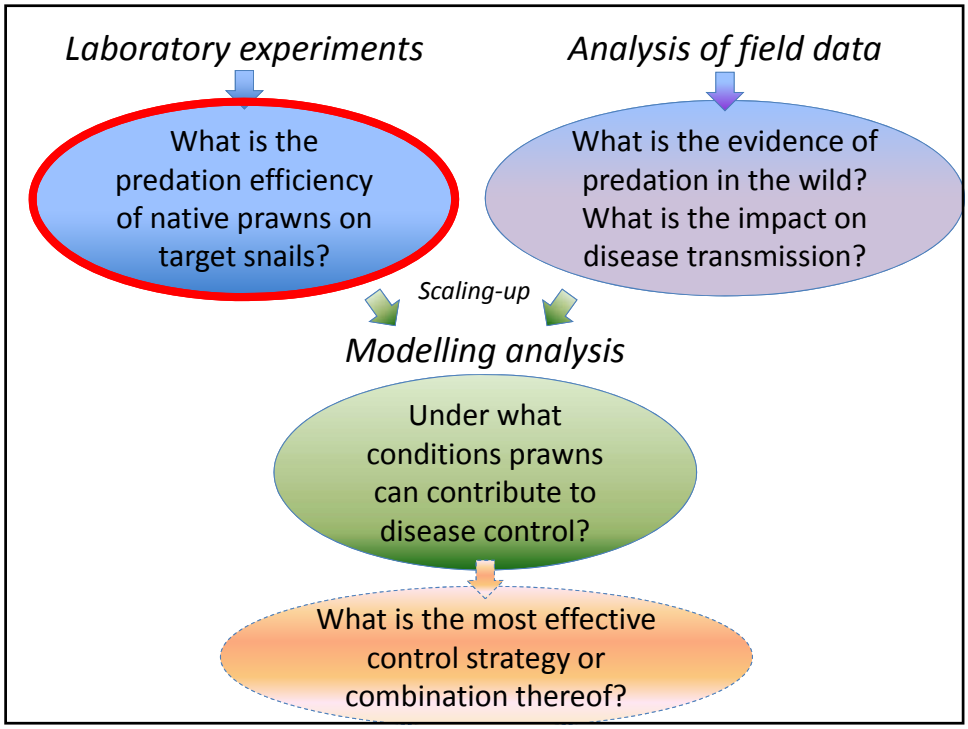


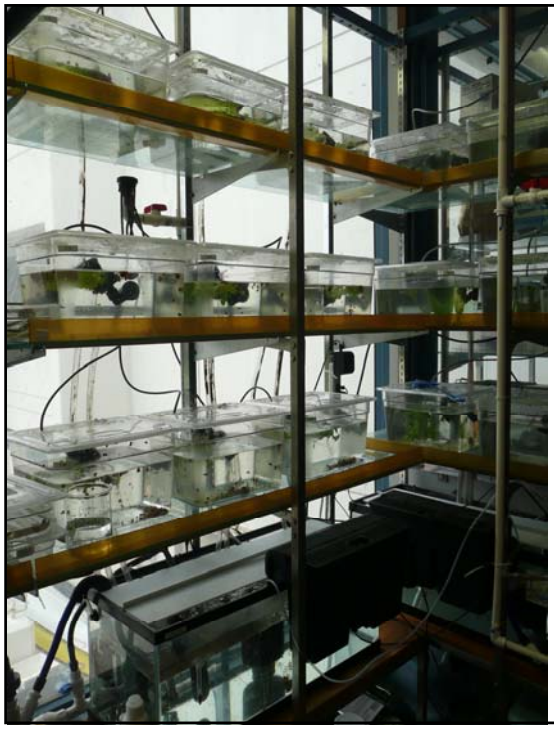












LABORATORY STUDIES

Sokolow et al. *Acta Tropica* 2013

Lab studies

Summary of the main results

Previous studies demonstrated that *Macrobrachium rosenbergii* are predators of *B. glabrata*

- Roberts and Kuris 1990, Lee et al 1983
- Jordan, 1985 The St. Lucia Project

Here, we show that the African native prawns *M. vollenhovenii* :

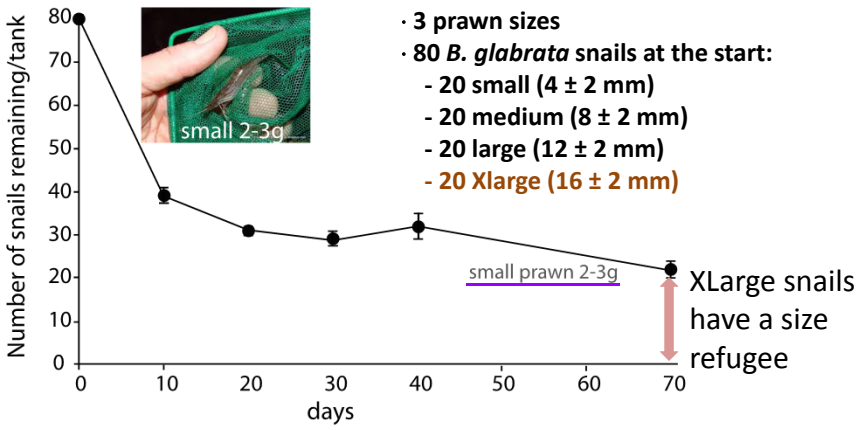
- **Are voracious snail predators**
- **Consume both *Biomphalaria* and *Bulinus* spp. snails**
- **Consume both infected and uninfected snails**
- **Exhibit snail consumption rates of 6 to 20 or more snails/prawn/day**

  depending on prawn and *snail size*

- All the experiments shown in the following were aimed at understanding accurately
  how many snails prawns eat per unit time
  as a function of:
  - prawn size
  - snail size
    - density
    - species
    - infectious status
- Without these data, it is difficult to make accurate predictions

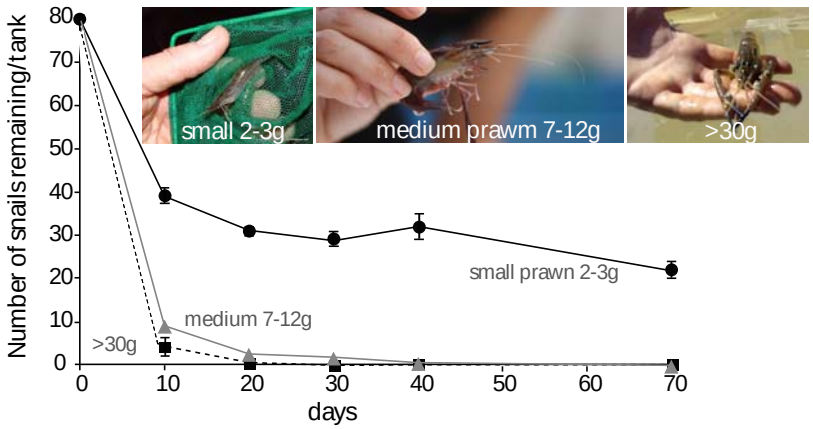
Does predation efficiency depend upon prawn size?

Sokolow et al Acta Tropica 2013



- **3 prawn sizes**
- **80 *B. glabrata* snails at the start:**
  - **20 small (4 ± 2 mm)**
  - **20 medium (8 ± 2 mm)**
  - **20 large (12 ± 2 mm)**
  - **20 Xlarge (16 ± 2 mm)**

Predation depends on prawn size

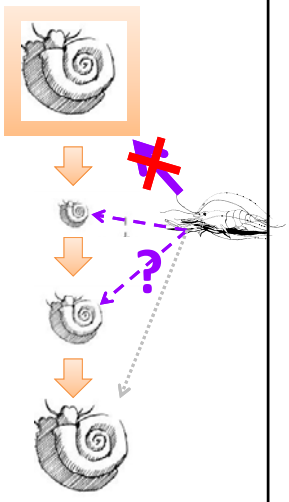


Sokolow et al Acta Tropica 2013

Do *small prawns* (<2-3 g) have any effect on *snail population growth*?

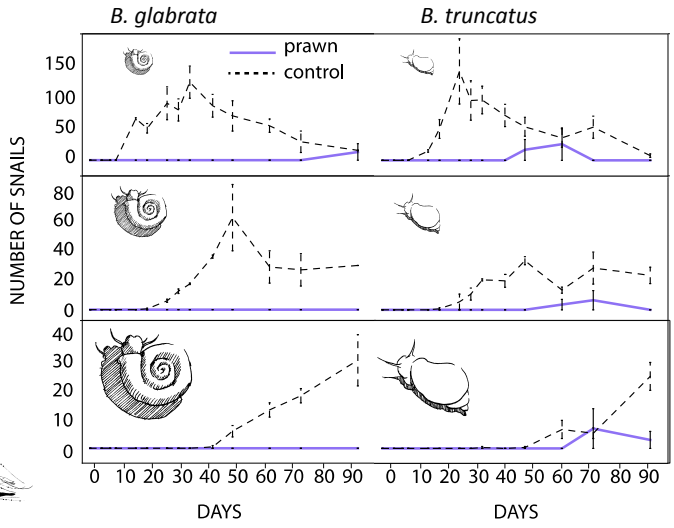
- Small prawns (<2 g) were set in tanks with large, pop. founder, egg-laying snails
- Then the emergence of offspring ("recruitment") of:
  - · small…
  - · then medium
  - · and finally large snails

  was monitored through time

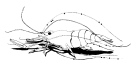


Sokolow et al Acta Tropica 2013

Small prawns can control snail population growth



Prawn (<2g):

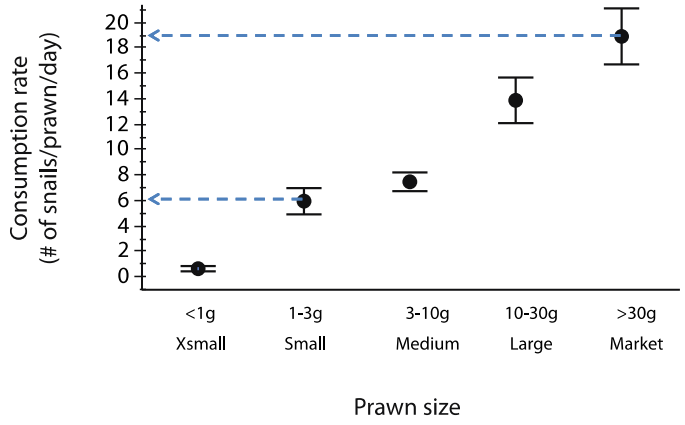


Sokolow et al Acta Tropica 2013

How many average-size snails can prawns of different size eat?

Predation rate

Snails > 4mm diameter

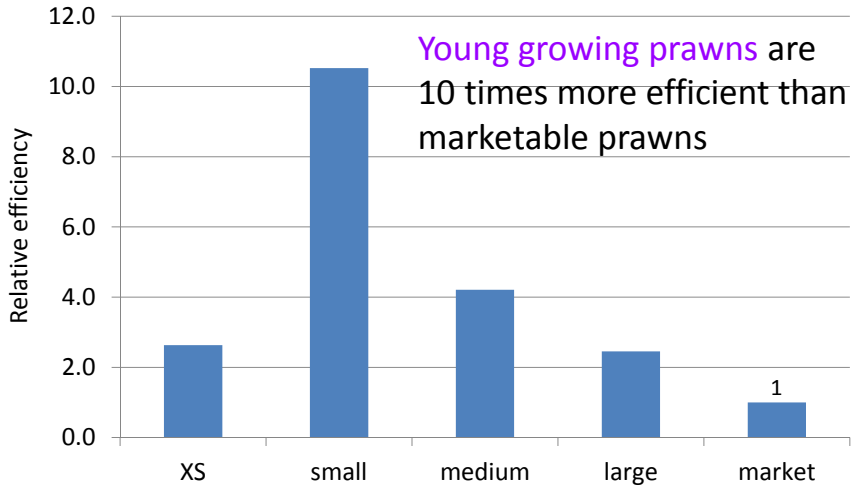


Sokolow et al Acta Tropica 2013

- **What prawn size is most efficient in removing snail?**
- **Does the goal of harvesting large prawnsconflict with the public health goal of eating as many snails as possible?**
- **If you can stock 1kg of prawns and want to control snail abundance, what is better?**
  to stock lots of tiny prawns
  or few large ones?

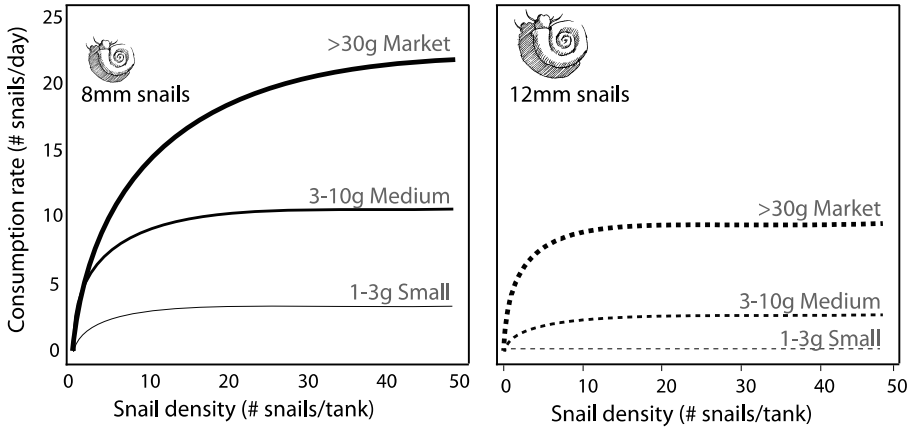
snails eaten per unit time

(predation rate of 1 kg of large prawns set to 1)



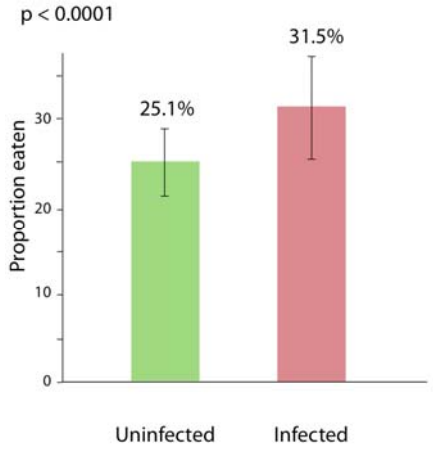
Young growing prawns are 10 times more efficient than marketable prawns

What is the effect of snail density on prawn consumption rate?



Are infected snails less likely to be predated than susceptible snails?

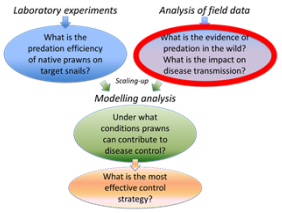
Prawns consumed more infected snails over uninfected



Summary of Predation Results

- Native prawns are voracious predators of both snail species
- Consume both infected and uninfected snails
- Prawn consumption rate is predictable, i.e. btw 6-20 depending upon snail/prawn body size
- Fishery and public health goals are compatible

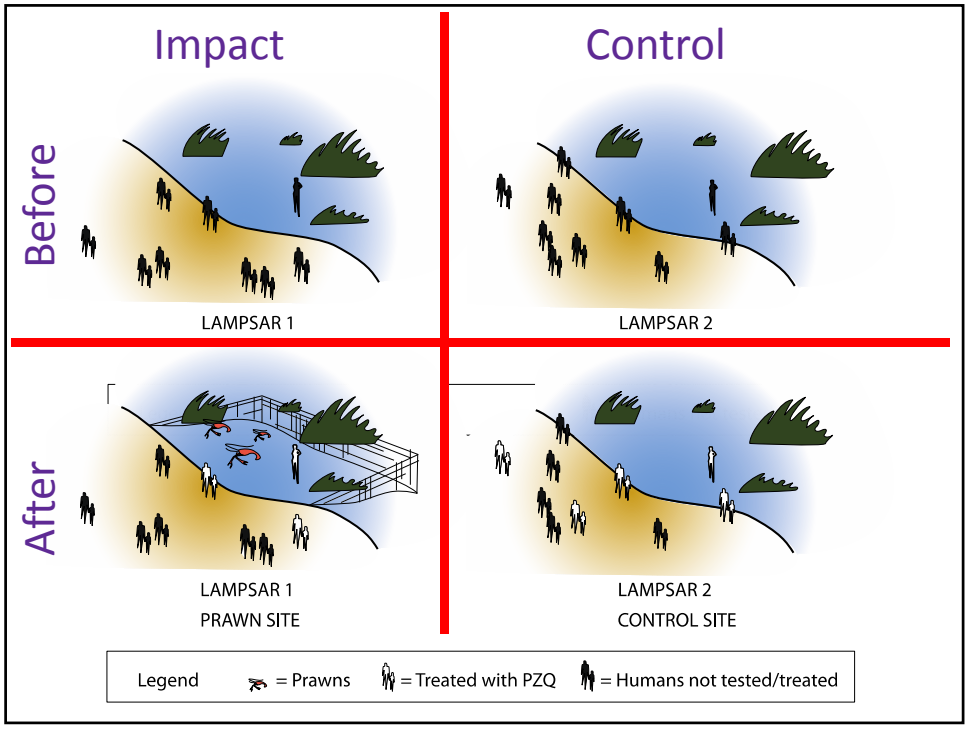
- So, prawns do eat snails in the lab experiments, but…
- Is there any evidence that they are doing it also in the wild?
- Does this have any measurable effect of disease transmission, in terms of prevalence and intensity of infection?



FIELD TRIALS SENEGAL RIVER BASIN 2011-2013

We present data from Lampsar 1 and 2, as it is a matched pair of villages that was monitored for the entire study period 2011-2013:

- once ***before***
- three times ***after*** prawns were installed



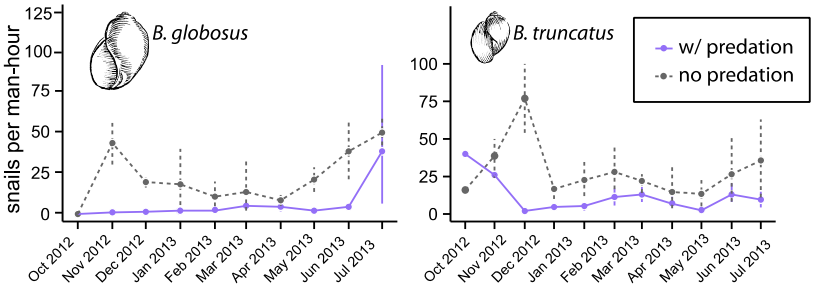
The net enclosure at Lampsar

Predation Effect

Total Snail Population was *lower in the prawn sites*

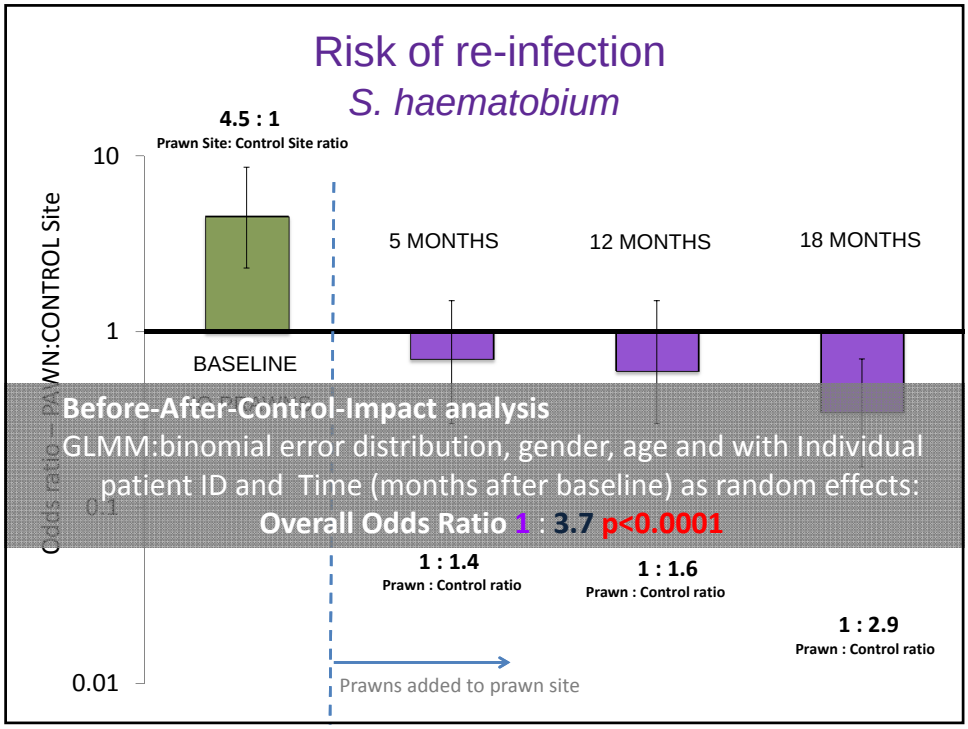
Prawn site was 50.4 ± 20% lower
$p < 0.0001$

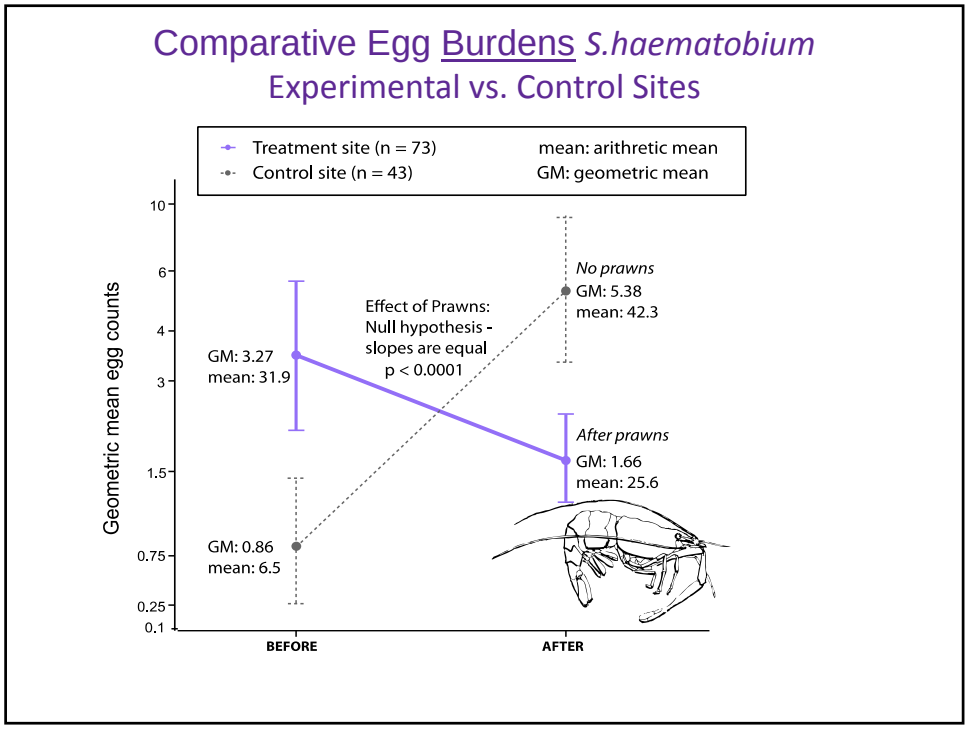
Prawn site was 58.8 ± 15% lower
$p < 0.0001$



What about human data?

Let's review the sampling scheme…





Summary of Field Research Findings:

1. Dramatically Fewer Infectious/Shedding Snails at Prawn site

- Prawns can sustainably lower the density of infected & SHEDDING snails

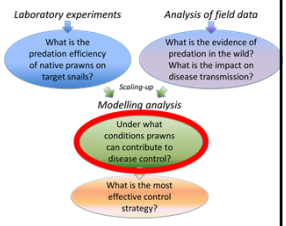
2.Lower Human Re-infection Rate at Prawn Site

- Prawns protect against re-infection after PZQ treatment

3. Lower Urine Egg Burdens For Those At Prawn Site

- Prawns reduce egg burdens, after PZQ treatment

- Why only few shedding snails at the prawns site?
- Still high reinfection rates at the prawn site: how many prawns do we need to stock to have a better control of the disease?
- If both MDA and prawns stocking are used is the effect additive or synergetic?



A NOVEL SCHISTOSOME TRANSMISSION MODEL

Mathematical models of Schistosomiasis

Mean number of parasites per person

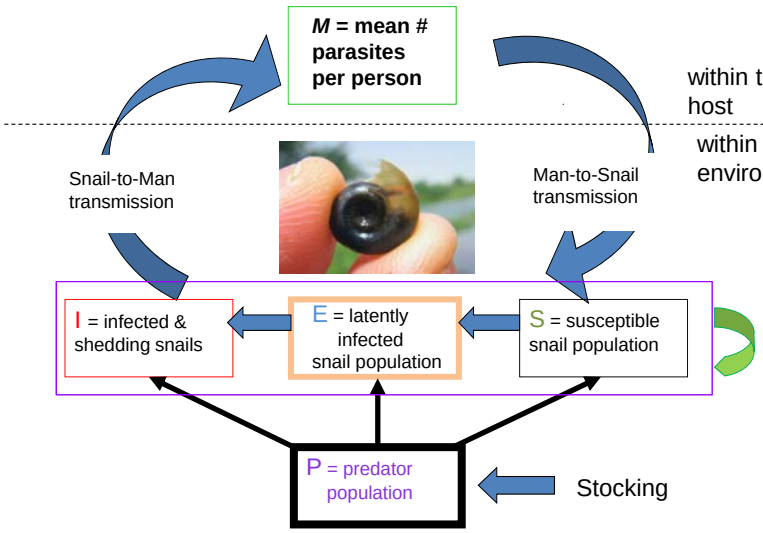
prevalence of infected snails

McDonald 1965
Woolhouse 1991 *Acta tropica*

$$\frac{dm}{dt} = \alpha N y - \gamma m$$

$$\frac{dy}{dt} = \beta H m(1-y) - \mu'' y$$

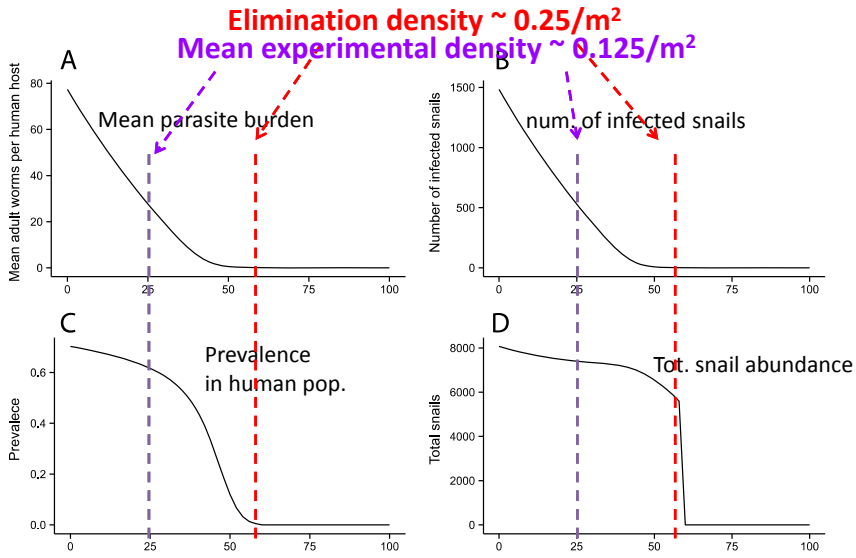
***m*: mean parasite burden**
***y*: disease prevalence in snauk**
***N*: snail number, constant**
***H*: human population**
No latent period in snails
No predation with functional response



1) Explicitly track the number of infected snails
2) Allow snail reproduction and replenishment and variable population size
3) Explicitly track the long latency time
4) **Account for prawn stocking, predation and functional response**

RESULTS

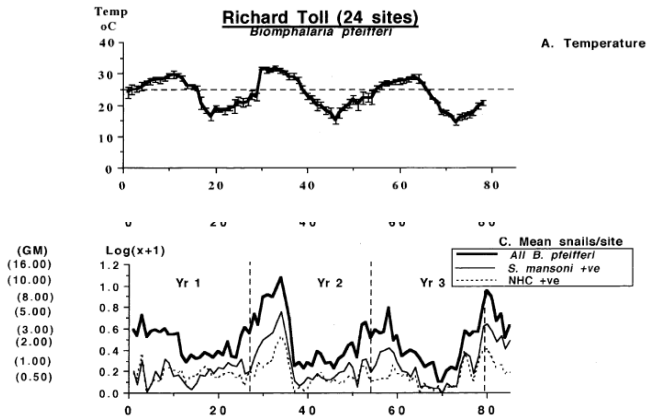
Equilibrium predictions



Why the effect on abundance of shedding snails is stronger than the effect on total snail abundance?

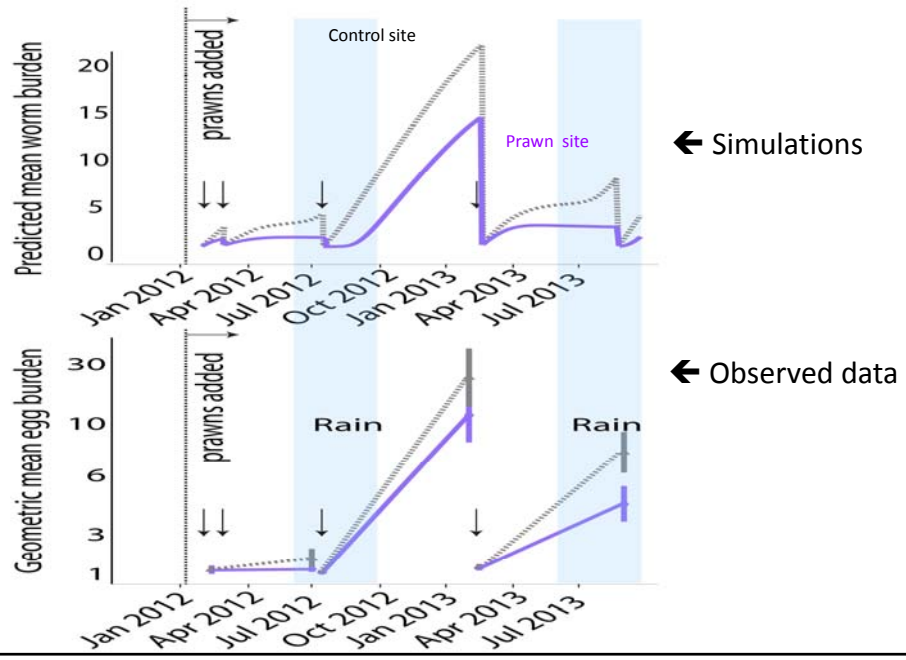
- Schistosomisis prepatent time is long and comparable to snail life expectancy
- Prawns reduces life expectancy of infective (*but not yet shedding snails*) just enough *to prevent them from shedding*
- Schisto reproductive number drops below 1 even though snail density remain significant
- If this is true, we shall expect a reduction not just in snail abundance but also in snail body size at the prawn site.

Seasonality



Sturrock et al. 2001 Parasitology

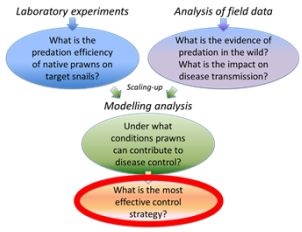
Simulations with seasonality in snail dynamics



Summary of Model Results:

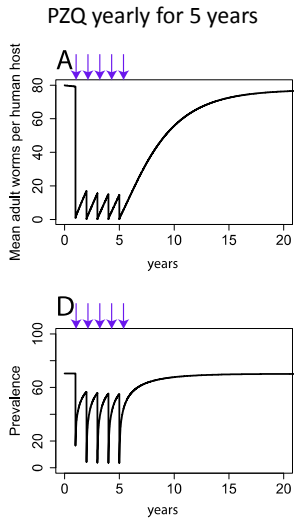
- Our model predictions fit well with observed patterns
- Restoring prawn population (whether through stocking or fish ladders) is likely to alleviate disease burden
- Stronger effect on:
  - # of shedding snails (vs. total snail pop.)
  - human egg burden (vs. prevalence of infection)

Scenario analysis

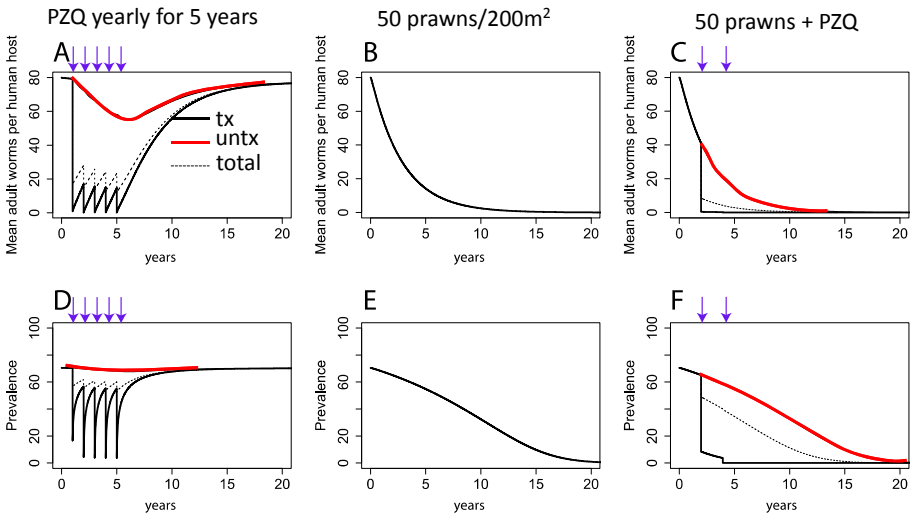


If both MDA and prawns stocking are used, is their effect additive or synergetic?

PZQ (80% coverage) vs "Prawns + PZQ"



Treated vs. untreated people



Conclusions

→The combination of prawn stocking with PZQ administration can deliver results that no such a measure can achieve alone

→local elimination becomes a more likely outcome if control of the natural snail reservoir through restoration of the prawn pop. is integrated with PZQ administration and other control strategies (sanitation, outreaching and education, etc.)

Current and future developments

- Historical analysis of control
- World-wide geographical analysis of prawns, dams and schisto
- Gates– scale up
- CNH – socio-economic models/assessment (optimization)
- EEID (Jason Rohr) – agriculture and schisto
- EPFL (Andrea Rinaldo) – hydrology and schisto
- Sanna and I – more detailed simulations/ optimal control/etc.