MALARIA R&D

For further information, please contact our New York office at:

Poseidon Science Foundation
122 East 42nd St., Suite 1700
New York, NY USA 10168
1-646-251-1661

Email:

info@poseidonsciences.com
poseidonnova@aol.com

Poseidon Science Foundation (PSF) is the non-profit organization of the Poseidon Sciences Group. Among PSF's primary missions are: (1) protect and preserve our aquatic environment; (2) develop livelihood technologies for coastal communities; and (3) develop biomedical and bio-industrial innovations derived from our aquatic resources.

Tropical Pesticide Research Institute (TPRI) is a multidisciplinary institute operating under the Ministry of Agriculture and Food Security of Tanzania and is responsible for pesticide regulation, health and safety, pest management and scientific research. TPRI started research work on Integrated Vector Management of mosquitoes and tsetse flies in 1946. TPRI collaborates with Government at all levels and across sectors, academic and service institutions, and NGO's to promote sustainable rural development through intervention in the different areas.

POSEIDON SCIENCE FOUNDATION
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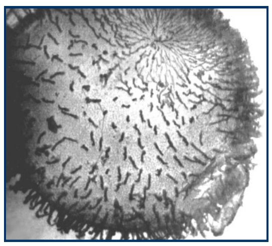
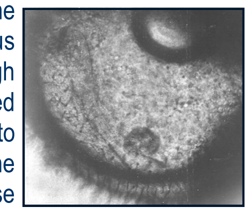
Poseidon Science Foundation and the government of Tanzania explore a vector control method using native larvivorous annual fish that mimic life cycle of malarial mosquitoes

Prevention of disease transmission by malarial mosquitoes requires a multifaceted approach, which includes killing mosquitoes with pesticides and larvicides. Biological control has now regained interest because of the resistance of mosquitoes to pesticides and to anti-malarial drugs, including artemisinin. The concept of using larvivorous fishes as an inexpensive biological control is an old concept, with some past successes. However, the introduction of the mosquitofish, *Gambusia affinis*, in new habitats has devastated indigenous freshwater organisms. Although local species of fish have been studied extensively as a means of larval control with notable success in India and parts of Africa, their effectiveness is limited only in permanent bodies of freshwater. Malarial mosquitoes are generally found in higher elevations in temporary pools that dry up seasonally, thus negating any initial control provided by larvivorous fishes or even chemical control agents. When the water dries up, the conventional fishes are decimated while the mosquitoes enter a dormant state until the next rains. Moreover, these malarial areas are generally inaccessible making vector control expensive and sporadic at best.



The ideal control method should be organisms that prey on mosquito larvae and can maintain permanent fish populations in temporary habitats. This fish population must be present when the rains come and as the hibernating eggs of mosquitoes begin to hatch. Annual fish represents a unique class of fish that survive in alternating dry and wet seasons by entering a state of dormancy or diapause, just like mosquitoes. The adults are decimated when the water dries up. The embryos, buried in the substrate during the previous breeding season, go through various phases of suspended animation or diapause to survive drought. When the rainy season arrives, these embryos hatch to feed on mosquito larvae.



annual fish embryo in diapause II

These fish are known to survive even in small depressions, such as water-filled elephant hoof prints. Annual fish are endemic to Africa and South America. The most extensively studied are those that belong to the genera *Nothobranchius* that occupy a wide range of habitats in Africa.

Nothobranchius guentheri is ideal for malaria vector control program because: (1) it can survive in temporary pools of freshwater; (2) its small size allows it to seek prey in between leaves and grass in shallow areas; (3) its small size also makes them less suitable to be used as food source by local human population; and (4) the species does not survive in permanent bodies of freshwater and thus pose no threat to other indigenous fishes.

Scientists from Poseidon Science Foundation have been working on developing mass production/ long term storage of the embryos in suspended animation and convenient methods of disseminating the embryos for eventual use in vector control. Moreover, the last three decades of research at Poseidon and by other biologists working in this field provided a better understanding of the life cycle of annual fish. Poseidon's collaboration with Tanzania's Tropical Pesticide Research Institute (TPRI) represents the most recent attempt to use these fishes for biological control. The project involves studies on methods of field introduction and monitoring of larvivorous activity in controlled test ponds. Field introductions will follow once the ecological, conservation and efficacy studies have been undertaken. Eventually, this effort will expand into mass production of the fishes locally and dissemination in malarial areas of Tanzania

male Nothobranchius guentheri

Photo courtesy of John Brill, LIKA

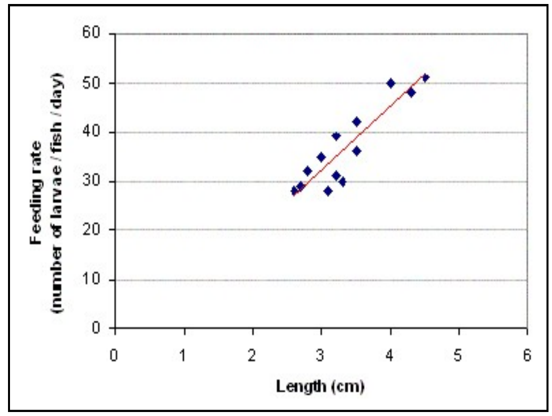
For more details about the biology and survival strategy of annual fish in nature, please see the links below:
http://www.poseidonsciences.com/annual_fish_biology_survival_strategy.pdf
http://www.poseidonsciences.com/annualfish.html
http://www.poseidonsciences.com/biocontrol.html

"This undertaking is pivotal. Once we are able to demonstrate the usefulness of this annual fish species for vector control in Tanzania, we can expand the same concept to other African countries where other native populations of annual fish exists."

Jonathan R. Matias, *Executive Director*
Poseidon Science Foundation

"***The research collaboration with Poseidon Sciences Foundation offers an opportunity to test novel, renewable and sustainable concepts that can help in vector control in Africa. We, at TPRI, are looking forward to working with Poseidon in this scientific endeavor."***

Shandalam Msangi, *Principal Investigator*
TPRI-Poseidon Programme



The relationship between feeding capacity on third instar mosquito larvae and length in the annual fish, N. guentheri.

Historical Perspectives

Yellow fever epidemics were common prior to the end of the 19th century. Until the seminal work by Carlos Finlay in 1881, no one understood the manner by which the disease was transmitted. The French attempt to build the Panama Canal in 1880 was stymied primarily by the loss of 21,900 lives as a result of yellow fever epidemics. During the Spanish-American War of 1898, yellow fever outbreaks prompted the US Surgeon General to send a medical team headed by Dr. Walter Reed, who finally proved Finlay's previous work that yellow fever was transmitted by the mosquito, *Aedes aegypti*. This basic understanding led to the clearing of stagnant pools, treatment of breeding grounds with chemicals and the use of bednets. The same vector control method was used when the Americans took over the construction from the French and successfully built the Panama Canal.

Also during this period, the use of fish was integrated in the biological control of the larval stages of mosquitoes. New Jersey was once called the *Mosquito State* because of the swarms of mosquitoes from the numerous estuaries dotting its shores. The introduction of *Gambusia affinis* (later called the mosquitofish) in New Jersey in 1905 was so successful that this fish was introduced worldwide for the same purpose, with dire consequences later on. *Gambusia* is a voracious predator and fed on all types of larvae including other fishes. It has a wide temperature and salinity tolerance and can reproduce at a faster rate than native fish species.

Gambusia

It was not until decades later that the impact of *Gambusia* on native fish populations became apparent. Many fish species became extinct wherever *Gambusia* was introduced because it aggressively attacks and outcompetes the native fish populations for food, particularly in New Zealand and Australia. It is also now becoming clear that the native fish populations, such as the pygmy perches, can be even more effective as predator of mosquito larvae. However, malarial mosquito breeding sites tend to be temporary so that even *Gambusia*'s efficacy as a biocontrol was limited.

In 1952, the noted ichthyologist, George Myers, made the first field observation that the annual fish may have potential in biological control of mosquitoes since mosquito bites were diminished in areas normally populated by these fish. By this time the widespread success in the use of the pesticide, DDT, had overshadowed the practical use of biocontrol and draining of stagnant pools. Funding in basic sciences declined along with the interest in both the private and public sector. Interest in this field was not rekindled until two decades later when the environmental impact of DDT to non-target species and the increasing tolerance of malarial mosquitoes to insecticides became more apparent.

In 1978 Jules Markofsky and I, while staff scientists at the Orentreich Foundation in New York, re-introduced Myer's idea during the Columbia University Seminars on Pollution and Water Resources. Although the concept was theoretically sound, there was so little known then about the biology of annual fishes, particularly the environmental cues that trigger the onset of diapause. Between 1978 and 1988, we began to focus our work on learning more about the mechanisms that control the onset and termination of diapause in annual fish. It was not until 1996, while I was working with Nova Pacific Research Foundation, that a grant from Conservation, Food and Health Foundation (Boston, Massachusetts) enabled us to conduct more practical studies on the predatory activity of the annual fish against mosquito larvae. And, finally in 2005 Poseidon Sciences began a more concerted effort in building the capability to move the project towards the field trials now being planned as part of the Poseidon-TPRI Biocontrol Programme in Tanzania.

The story of biocontrol using fish has taken a full circle, with over a century of history behind it. The story that annual fish plays is just beginning. While it is not the perfect answer, it might very well become part of an overall solution someday.

J. R. Matias