Snail Control by Fish: An Explanation for Its Failure

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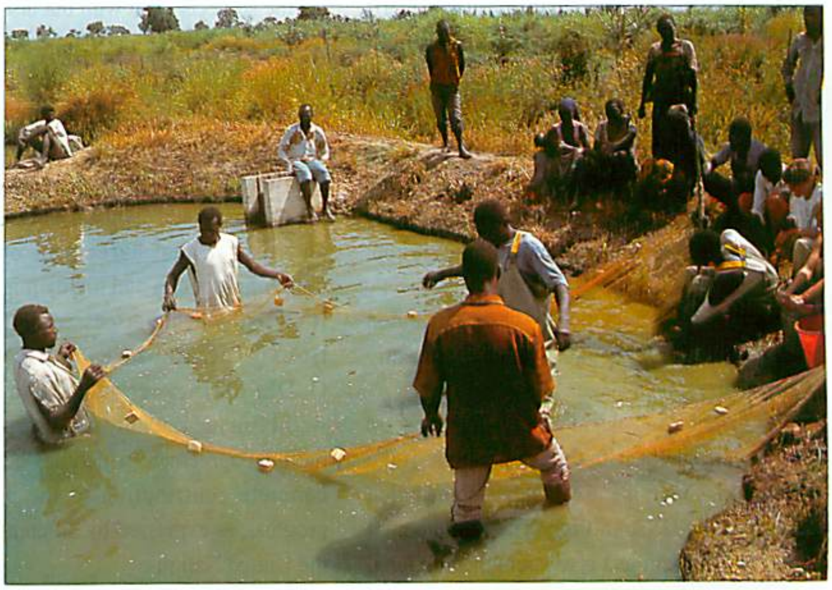
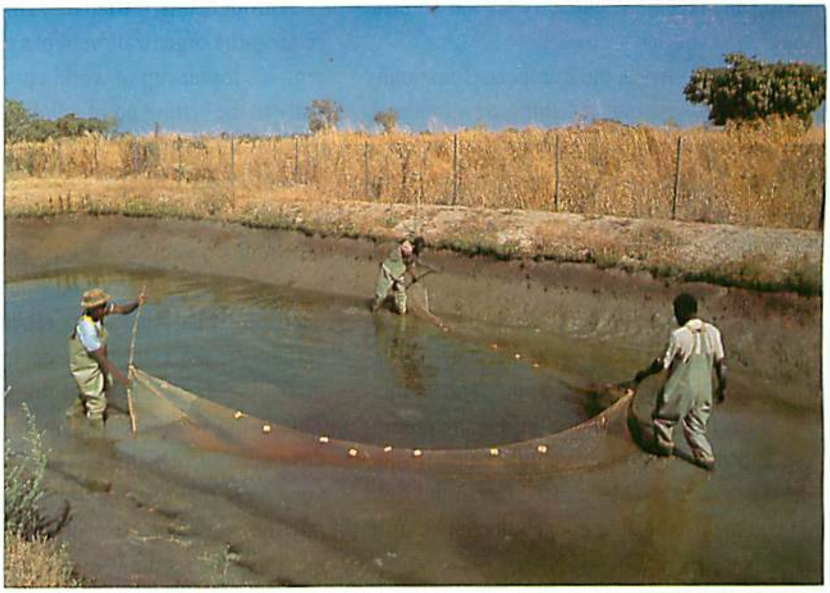
Systematic studies on the performance of fish as snail eaters in waterbodies are rare. Here, trials with a promising African cichlid revealed that the fish were only successful at reducing snail populations if there was nothing better to eat — and this is hardly the case. The fish need solid jaws to crush the snails but do not develop such jaws if they can find other, preferables foods. The prospects for this form of control are also discussed in the broader context.





Activities at the Gounougou Aquaculture Centre, Cameroon.

Why Snail Control by Fish?

An estimated 200 million people are infected worldwide by the five known species of human schistosomes, worm parasites which are transmitted by various species of freshwater snails. The resulting disease, schistosomiasis (or bilharzia), causes significant illness to man. Several other trematode parasites are known to affect fish and cattle causing serious economic damage. Effective medicines against schistosomiasis exist nowadays, but the rapid reinfection that often occurs after treatment and the high cost of repeated medication have tempered expectations of the efficacy of medication campaigns on longer term.

Actions to reduce the risk of transmission by controlling the snail hosts often remain necessary. Snail control can be realized by means of (1) application of molluscicides, (2) habitat modification such as removal of vegetation, concrete lining of ponds and canals, and (3) biological control. Molluscicides have the disadvantage of being expensive and toxic to fish and other useful organisms. Habitat modification is also expensive and of limited applicability, usually only in man-made environments. Biological control by fish has often been suggested for aquaculture ponds, irrigation canals, and in combination with rice-fish culture.

In spite of the general agreement that fish can affect snail populations directly or indirectly, the unsystematic character of early experiments on control of snails by fish has precluded the growth of a consistent body of knowledge. This is reflected in the scientific literature where researchers are repeatedly urged to perform systematic research into this matter. Only a few well documented field trials exist, which report varying degrees of success with species such as the black carp (*Mylopharyngodon piceus*), the shellcracker sunfish (*Lepomis microlophus*), and the African cichlids *Astatoreochromis alluaudi* and *Serranochromis mellandi*.

Astatoreochromis alluaudi, Africa's Best Studied Snail Eater

One species, subjected to several field trips in the past, has often been mentioned as a possible candidate, i.e., the East African haplochromine cichlid *Astatoreochromis alluaudi*. Recent field and laboratory work has revealed much needed information on its performance in snail control. This fish is common to Lake Victoria and several other East African lakes and rivers. In Lake Victoria this species is predominantly found in the littoral zone and feeds mainly on the thick-shelled mollusc *Melanoides tuberculata* by crushing the shells with its pharyngeal jaws.

Field observations in one particular small lake near Lake Victoria, where *M. tuberculata* were known to be absent, showed that fish had less developed pharyngeal jaws and that they had fed on insects. Laboratory experiments with *A. alluaudi* and other snail crushing cichlids raised on *Biomphalaria glabrata* snails show that fish that feed on this thin shelled snail do not develop the heavy jaws which characterize the Lake Victoria specimens. So not only eating of snails but also the hardness of the shell determines the level of development of the pharyngeal jaws. A good measure to differentiate between animals with heavily developed jaws and those with light jaws is the horn width of the lower paragraph element (see Fig. 1).

In Nyanza Province, Kenya, control of snails was attempted in 1955 by the introduction of *A. alluaudi* in earthen dams. The data indicate that *A. alluaudi* did initially reduce the numbers of some species of snails, but the results are not very conclusive. In 1986/87, eight of the dam sites were revisited in order to see whether *A. alluaudi* was still present and to assess the effect on snail populations. In five sites the fish was recaptured; in one case it was the most abundant species. Nevertheless, snails were found in abundance. From every dam site several fish were collected in order to study the dentition of the pharyngeal jaw apparatus. All specimens showed the reduced type of pharyngeal jaws.

In 1962, a field experiment was performed in the south of Cameroon. Wild caught *A. alluaudi* were taken from Uganda to the south of Cameroon where pond trials showed that snails were effectively controlled, and that *A. alluaudi* could be successfully cultured together with Nile tilapia. The described experiments cover only one fish production cycle; it is not known if the technique was used for a longer period and if this successful snail control was repeated more often. A reconnaissance tour in 1987, however, did not reveal any remaining *A. alluaudi* in aquaculture stations in Cameroon.

Another field trial with *A. alluaudi* in Cameroon started in 1988 in the aquaculture station of Gounougou, situated in the Benue valley of the Northern Province of Cameroon. Results on the trials with *A. alluaudi* in combination with catfish (*Clarias gariepinus*) and Nile tilapia (*Oreochromis niloticus*) showed that neither catfish, a known snail eater, nor *A. alluaudi* had any influence on resident snail populations in ponds. In fact, only a minor but significant reduction in snail numbers could be shown in presence of adult Nile tilapia, known to be an omnivorous fish. In terms of controlling the transmission of parasites, however, this reduction in numbers of snails was insignificant. The major conclusion of the study was that fish culture under good nutritional regimes enhances growth and reproduction of snails. Because of a lack of competition for food the so-called molluscivorous fish prefer to eat "easier" food items, readily available in fishponds. Field trials in drainage canals and in a rice-fish culture experiment gave additional evidence that the fish were not capable of controlling snails.

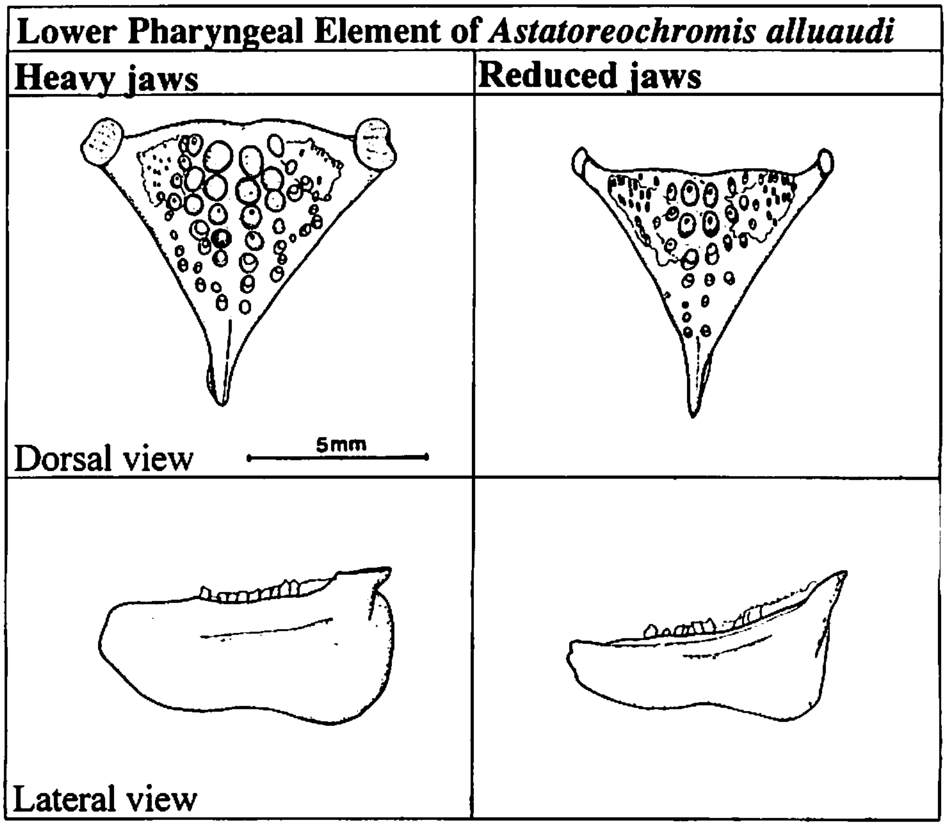


Fig. 1. The pharyngeal jaws of a wild-caught Lake Victoria specimen with heavy jaws and a laboratory-reared specimen with reduced jaws. The jaw muscles are attached to the horns; their width is a good measure for the development of the pharyngeal jaw.

Three Reasons for Failure of *Astatoreochromis alluaudi*

Foraging Behavior and Prey Choice

The prey choice of a wide range of animal species searching for food can and has been explained by foraging models. In the most simple foraging model the parameters energy content of prey, the handling time (time required for searching and processing a prey), and encounter rate (numbers of prey encountered per unit of time) have to be known. When offered a choice of different prey types, these preys can be classified according to their profitability, defined as the energetic yield divided by the handling time. According to the average-rate maximizing model, a predator will, upon encounter, always accept the type of prey with highest profitability (type 1). The prey type rating second in energy yield (type 2) will only be accepted if the total energy yield when foraging on both prey types is larger than the yield when only type 1 prey is chosen. Mathematically it can be shown that the encounter rate with the highest yielding prey (type 1) must be lower than a certain threshold before prey type 2 will be eaten. In other words, the acceptance of a lower-ranked prey type is not influenced by its own density but by the density of the higher-ranking prey type only. When snail-eating cichlids are offered a combination of insect larvae and snails, insect larvae have a higher yield (energy/handling time), and hence are the most profitable prey type. Snails will thus only be eaten when the encounter-rate with insects is below a certain threshold. For field conditions this implies that the willingness of the fish to eat snails does not depend on the amount of available snails but on the amount of other, more profitable food items. Especially in aquaculture situations the amount of food will not be a limiting factor, because fish have to be produced at the highest possible growth rate and "easy" food (i.e., of the most profitable type) is provided in abundance. If fish forage optimally, they will in this case never switch to eating snails. This observation corroborates with the hypothesis that in Lake Victoria the fish only specialize on snails under the pressure of heavy competition with other fish species that are better equipped to handle these other food items.

Plasticity of the Pharyngeal Jaws

The absence of heavily developed pharyngeal jaws reduces the fishes' capability to crush snails. This does not imply that they are not able to eat snails but that handling times for the crushing of snails will increase, especially for larger snails. Following the foraging model, the encounter rate with more profitable prey types must decrease even further before snails are included in the fishes' diet. The combination of optimal foraging theory and the functional morphology of the pharyngeal jaws allows us to understand the initial partial success of *A. alluaudi* in Kenya, where later observations showed that the fish had no influence at all on snail densities, even in reservoirs where fish were still abundant. The introduced fish were wild-caught animals from Lake Victoria with almost certainly heavily developed pharyngeal jaws. The initial small reduction in snail numbers was caused by this wild-caught generation. In due course this generation was replaced by next generations with less developed jaws. Competition for food in the reservoirs might be low compared to Lake Victoria because they lack an endemic fish fauna. Furthermore, the hardshelled *Melanoides tuberculata* or similar snails do not occur in these reservoirs. Thus, the necessary conditions to develop heavy jaws are absent. The resulting omnivorous fish is capable of eating snails, but does not specialize on these and consequently also does not search for them. Probably the phenomenon described above also affected the early experiments in Cameroon. For this trial also wild-caught *A. alluaudi* were imported from Lake Victoria. After the initial success, the fish was never again heard of supposedly because the next generation of pond-reared fish did not eat snails at all.

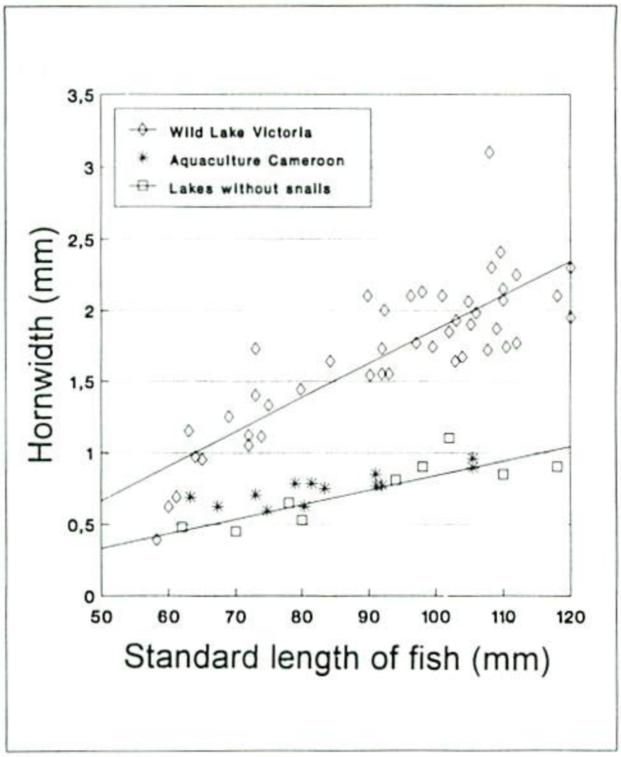


Fig. 2. Reduction of the pharyngeal jaws in A. alluaudi *reared in the aquaculture station of Gounougou, North Cameroon. Pond-reared specimens fall within the range of fish with the reduced type of jaws.*

Snail Ecology

Other factors reducing the efficacy of snail-eating fish are the spatial distribution of snails and the snails' reproductive capacity. Except for the host snail of oriental schistosomiasis, *Oncomelania* spp., all other schistosomiasis vector snails are pulmonate snails, dependent of oxygen-rich water near the surface. Usually they are found at the fringes of a water reservoir or on floating vegetation. Although *A. alluaudi* and some other molluscivorous cichlids are shallow water animals, behavioral studies and the high detritus

Experimental introduction in a screened section of a drainage canal.

Astatoreochromis alluaudi *male in active coloration.*

content of their stomachs indicate that they are bottom feeders. The reproductive capacity of snails is enormous; research suggests that food rather than the number of offspring is the limiting factor in the colonization of habitats.

Prospects for the Use of Fish in Snail Control

In the preceding section, reasons for the failure of *Astatoreochromis alluaudi* in snail control are given. Other species of snail-eating cichlids will also fail to control molluscs for the same reasons. Many examples of variability within the cichlid family are known. Therefore, it is likely that the reduction of the pharyngeal jaw apparatus is not limited to *A. alluaudi* only. Problems related to the foraging behavior will probably not differ much among the many other snail-eating lacustrine cichlids. Therefore, it does not seem advisable to invest further research efforts into this group. Snail-eating fish from other families might be unsuitable as well, either because of their omnivorous foraging behavior or because they are bottom feeders. They appear to be effective against snails in tank experiments, but under field conditions they prefer to forage on other prey items.

However, several examples of snail control by fish from the literature cannot be neglected. The shellcracker sunfish, *Lepomis microlophus*, successfully controlled snails in Puerto Rico, but from the available data it is not clear whether schistosomiasis transmission was interrupted. A renewed visit to the lakes where this species has been introduced, such as has been done in Kenya, would give valuable additional information. The black carp, *Mylopharyngodon piceus*, was effective in controlling nuisance snails, obstructing water meters and irrigation equipment in reservoirs in Israel. The method of fish culture and integrated control as applied in Israel is restricted to a limited number of environments and requires knowledge on aquaculture and limnology. However, more research on the reproduction methods and usefulness of this species in snail control seems justified, especially in relation to aquaculture. Convincing field evidence comes from Zaire where the riverine cichlid *Serranochromis mellandi* was successful in controlling molluscs in fishponds, irrigation canals and ricefields. Unfortunately, no recent information is available on this species; the latest publication dates back to 1956.

From the available evidence it has become clear that *if* fish were to be used in snail control, it should be limited to permanent habitats and in combination with other control measures. The role of fish must be seen as part of an integrated approach where habitat alterations and appropriate water management can reduce snail breeding and refuge sites, and where natural or introduced competitors and predators put further pressure on snail populations. Studies on the population dynamics of snails have shown that the availability of food is often the major constraint. The introduction of the Chinese grass carp (*Ctenopharyngodon idella*) in irrigation canals in Egypt had a significant reducing effect on snail populations. Clearing of aquatic weeds reduces the amount of food and also exposes snails to predators that might be naturally present. Even if these predators are omnivorous their contribution in the reduction of snail populations might be considerable if the environment is made more hostile to snails. Future research activities should concentrate on this area of integrated research, rather than hoping to find a fish predator of snails that will fully eradicate intermediate hosts of schistosomiasis and other trematode parasites.

Further Reading

Slootweg, R., P. Vroeg and S. Wiersma. 1993. The effects of molluscivorous fish, water quality and pond management on the development of schistosomiasis vector snails in aquaculture ponds in North Cameroon. Aquacult. Fish. Manage. 24:123-128.

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