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SHORT COMMUNICATION

Effects of molluscivorous fish, water quality and pond management on the development of schistosomiasis vector snails in aquaculture ponds

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One of the possible negative side-effects of aquaculture in tropical areas is the spread of water-related diseases, in particular schistosomiasis. Fish ponds can provide breeding sites for freshwater snails transmitting schistosomiasis (Berrie 1966). Scientific attention has long been concentrated on the use of molluscicides as the most effective means of snail and schistosomiasis control. However, molluscicides have limited use in aquaculture as they are expensive, hazardous to many other forms of aquatic life including fish, and have to be applied regularly because of the rapid recolonization by snails. This paper describes a study made on snail populations in an aquaculture station in northern Cameroon and their possible relation with water quality, pond management and cultured fish species. Together with production experiments, the development of snail populations in the fish ponds has been monitored during 2 years, and the biological control potentiality of two fish species has been tested. The experiments are part of a larger programme on the integrated control of schistosomiasis in the upper Benue Valley of northern Cameroon (Slootweg 1991).

Three species of fish were used in the pond experiments. The tilapia, *Oreochromis niloticus* (L.), was used for production experiments under different nutritional regimes. To control the excessive reproduction by *O. niloticus,* the African catfish, *Clarias gariepinus* Burchell, was introduced in several experiments. *C. gariepinus* is also known to eat snails; based on stomach contents analyses of fish caught in an irrigation scheme in Sudan, Coates (1984) suggested using *C. gariepinus* in the control of schistosomiasis vector snails. As a third species, the East African cichlid fish *Astatoreochromis alluaudi* Pellegrin was introduced solely to test its capability to control molluscs (Slootweg 1989). In the literature *A. alluaudi* has often been recommended as a means of biological snail control, but the number of actual field trials is very limited. One experiment in Kenya showed a significant reduction in snail populations over a long period (McMahon 1960; McMahon, Highton & Marshall 1977), although contradictory evidence is given by recent research (Kat & Kibberenge 1990). One successful experiment has been described from an aquaculture station near Yaoundé in Cameroon (Bard & Mvogo 1963; Mvogo & Bard 1964), but has never been repeated afterwards.

The aquaculture station of Gounougou (North Province, Cameroon) consists of 12 small

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ponds (25 × 10 × 0·9 m: 250 m^2 floor surface) used for production of fingerlings and storage, and 12 larger ponds (35 × 15 × 1 m: 525 m^2) for production experiments. Water supply to every pond can be regulated separately by means of supply-pipe and a concrete drainage monk. Pond experiments lasted from 8 to 45 weeks. Between experimental cycles the ponds were routinely drained and dried for at least one week to stimulate the decomposition of benthic deposits. The station is managed intensively; all vegetation in and around ponds is cleared regularly and unauthorized visitors (except cormorants and kingfishers) are kept outside by an iron fence. Snail sampling was carried out on a monthly routine basis. Each pond was sampled for 10 min by one person using a small net. In this paper only the two most frequently occurring snail species are considered: *Bulinus forskali* (Ehrenberg) and *Bulinus truncatus* (Audouin).

Data on 79 experiments were collected between May 1989 and March 1991. Complete sets of data on all variables are available on 62 experiments; in 17 experiments one or more variables had to be treated as missing values. Three products were used as fish feed and/or pond fertilizer: brewery waste (used 46 times), cotton seed cake (40), and cow manure (8). During the experiments visibility and temperature were measured weekly at 0800 h. Stocking densities of fish usually varied between 0·5/m^2 (adults) to 5/m^2 (juveniles) for *O. niloticus,* and 0·1–2/m^2 for *A. alluaudi* and *C. gariepinus.* Initial stocking density, and the presence or absence of a species in an experiment were used as a variable. As *O. niloticus* were always present in the experiments, a distinction was made between the presence of adults (26 experiments) or juveniles (39 experiments). *A. alluaudi* was introduced 11 times and *C. gariepinus* 33 times in 71 experiments. To test whether the numbers of snails were significantly correlated to the numerical variables, the Spearman rank correlation test was applied (Table 1). The binary sets of data (presence = 1 *vs* absence = 0) were tested with the binomial test, as explained in Table 2 (Siegel & Castellan 1989). The level of significance is determined at 10%.

The development of the snail population throughout the experimental period is summarized in Fig. 1. The results in the experiments show hardly any significant correlation between snail densities and one of the variables concerning water quality, pond management and fish species (Table 1 for numerical variables; Table 2 for binary variables)

Table 1. Spearman rank correlation test on numerical variables (Ponds 1–12: number of experiments is 36; ponds 13–24: number of experiments is 43)

	B. truncatus	Secchi disk	Temperature (0800 h)	Duration	Stocking density (*O. niloticus*)	Stocking density (*C. gariepinnus*)	Stocking density (*A. alluadi*)
B. forskali Ponds 1–12	r = 0·24 P = 0·14	r = 0·17 P = 0·31	r = 0·04 P = 0·79	r = 0·11 P = 0·49	r = −0·65 P = 0·70	r = −0·16 P = 0·35	r = 0·07 P = 0·67
B. truncatus Ponds 1–12		r = 0·07 P = 0·68	r = 0·12 P = 0·45	r = 0·12 P = 0·45	**r = 0·41** **P = 0·02**	r = −0·15 P = 0·35	r = 0·16 P = 0·33
B. forskali Ponds 13–24	**r = 0·51** **P = 0·004**	r = −0·14 P = 0·32	r = −0·04 P = 0·81	r = −0·05 P = 0·78	r = 0·17 P = 0·29	r = −0·11 P = 0·48	**r = 0·27** **P = 0·07**
B. truncatus Ponds 13–24		**r = −0·26** **P = 0·07**	r = −0·21 P = 0·15	r = 0·03 P = 0·82	**r = 0·41** **P = 0·01**	r = 0·07 P = 0·65	r = −0·07 P = 0·64

r = correlation coefficient; P = significance levels; significant levels under 10% in bold.

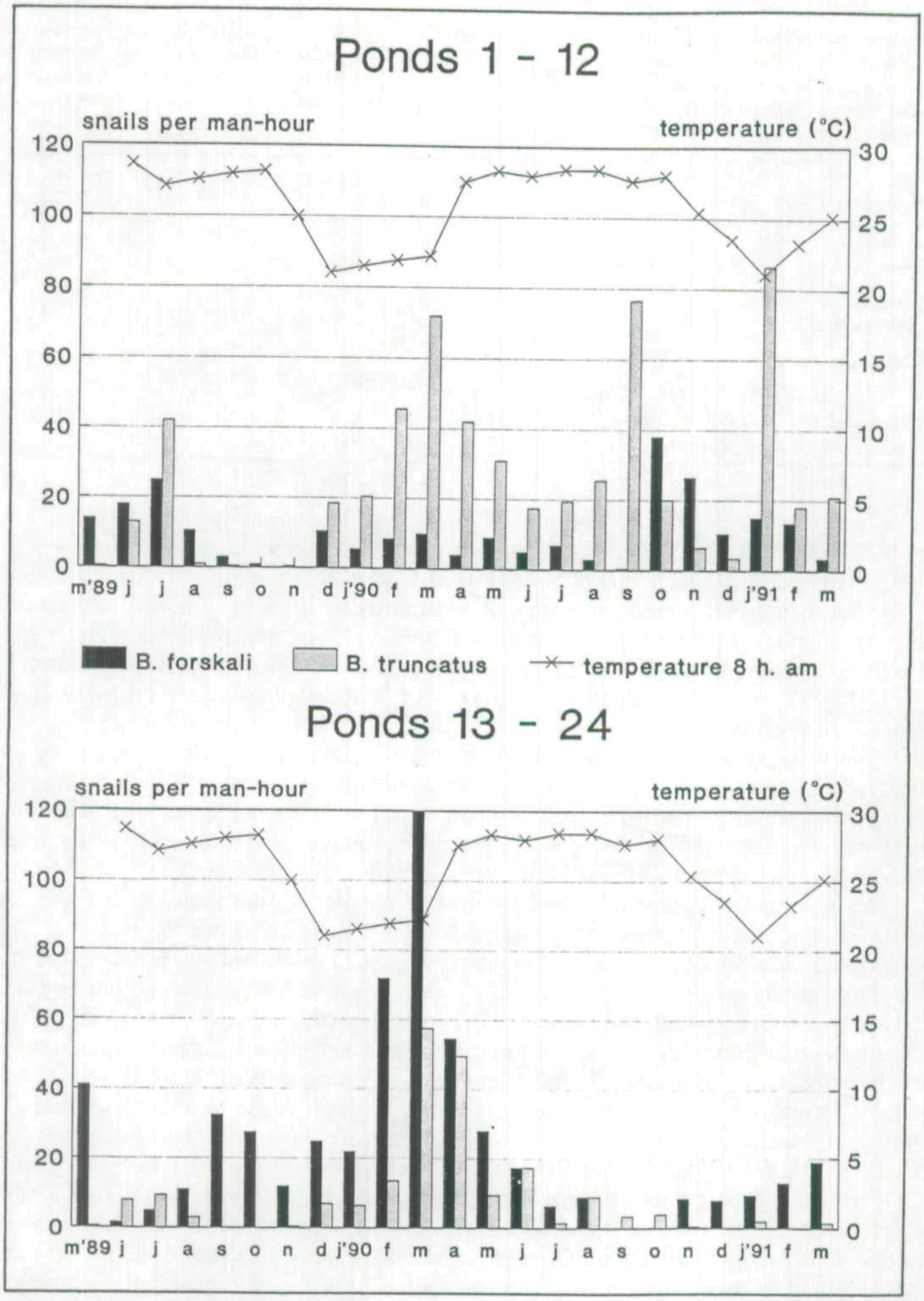
Table 2. Binomial test; probability levels for binary datasets. Data were sorted according to descending order of the numerical variable shown in left column. The frequency of occurrence in the first half of the sorted array was tested to the expected frequency (i.e. the frequency in *all* trials). H_0: the frequency in the first half of the array does not differ from the overal frequency. Upper left: number of trials. Lower left: frequency higher (+) resp. lower (−) than predicted. Lower right: probability

Presence of:	*A. alluaudi*		*Clarias*		Adult *Oreochromis*		Brewery waste		Cotton seed cake		Manure	
B. forskali	38		36		36		30		30		30	
Ponds 1–12	+	0·44	−	0·49	+	0·60	−	0·59	+	0·62	−	0·52
B. truncatus	38		36		36		30		30		**30**	
Ponds 1–12	+	0·25	−	0·23	+	0·60	−	0·59	+	0·13	−	**0·06**
B. forskali	48		42		40		36		36		36	
Ponds 13–24	+	0·16	−	0·35	−	0·40	+	0·22	+	0·18	−	0·22
B. truncatus	48		42		**40**		36		36		36	
Ponds 13–24	−	0·51	+	0·40	−	**0·08**	−	0·43	+	0·49	+	0·43

Water quality. B. forskali does not relate to any of the environment factors water turbidity, water temperature, or type of pond fertilizer. Apparently, for this pioneering species the pond habitat is suited to its establishment. *B. truncatus* shows a little more dependency on water turbidity and type of pond fertilizer. In ponds 13–24 *B. truncatus* is found more often in turbid water (Table 1). We suppose that nutrient level is the determinant factor for turbidity in fish ponds. The use of manure reduces the number of *B. truncatus* in ponds 1–12 (Table 2), but only three experiments in 30 included manure so this result is not considered conclusive.

Pond management. Surprising is the absence of any relation between snail numbers and the length of the experiment. One would expect that snails need some time to get established in a pond after it has been drained and dried, but apparently this is not true. The most probable presence of aestivating snail specimens in the mud can explain the rapid recolonization of the ponds after the start of a new fish production cycle.

Fish species. No significant reductions in snail populations have been found with the introduction of the specialized snail-eating cichlid *A. alluaudi,* nor with *C. gariepinus.* The idea that *A. alluaudi* can control snail populations is quite dramatically contradicted by the significant positive correlation between *B. forskali* snails and *A. alluaudi* in ponds 13–24 (Table 1). Obviously *A. alluaudi* is able to live on a diet different to its natural habitat, and apparently even prefers this diet to eating snails. The lack of effect of *C. gariepinus* on snails can be explained by its habits. The fish is known to be an opportunistic bottom feeder. In its natural habitat the fish randomly finds prosobranch snails on the bottom of a reservoir. Pulmonate snails (all African schistosomiasis vectors are pulmonate) usually are surface dwellers, not descending further than 25 cm. The fish simply does not meet the snails. Unfortunately, Coates (1984) did not mention the species of snails found in the stomachs of *C. gariepinus* caught in irrigation systems in Sudan. Remarkably, the only influence on snails by fish could be shown with adult *O. niloticus* on *B. truncatus,* although it must be stressed that sufficient numbers of snails remain to allow schistosomiasis transmission. In ponds 1–12 we found a negative correlation between *B. truncatus* snails and density of *O. niloticus* (Table 1). In ponds 13–24 higher stocking density correlates to a higher snail density, which at first sight is in contradiction with the aforementioned reduction. An explanation for this



Ponds 1 - 12

Ponds 13 - 24

Figure 1. Total numbers of snails collected in ponds 1–12 (reproduction and storage) and ponds 13–24 (production experiments) at the aquaculture station of Gounougou from March 1989 until March 1991, and the montly average water temperature at 0800 h in the morning. Snail collections are expressed as the number collected per man-hour search-time.

phenomenon can be found in the experimental set-up. In production ponds (13–24) adult fish are always stocked in lower densities than juveniles, whereas in the storage ponds (1–12) adults can be found in higher densities. Hence, only the adults have a reducing effect on *B. truncatus* populations. This observation corresponds to the significant reduction in *B. truncatus* snails in the presence of adult tilapia in ponds 13–24 (Table 2).

In the aquaculture station of Gounougou in north Cameroon it appeared to be very difficult to prevent the establishment of schistosomiasis vector snails in fish ponds. Even in ponds with hardly any vegetation, high stocking densities of fish, regular drainage and drying, and in the presence of known snail-eating fishes, snails establish themselves without being significantly affected. To be able to show some relationship with factors that might influence snail populations, we raised the level of significance to 10%. This is not considered to be very convincing. Briefly, the reasons for failure of the mollusc-crushing cichlid *Astatoreochromis alluaudi* can be found in the spatial distribution of snails, and in the foraging behaviour and anatomy of the fish. Competition in its original habitat, Lake Victoria, forces the fish to forage on hard-shelled prosobranch snails; compared to wild-caught fish, the aquaculture specimens showed a reduction in size of the pharyngeal jaws and in strength of the pharyngeal jaw muscles (used to crush the snails shells). The foraging efficiency and prey choice will consequently be irreversibly altered (viz. Slootweg 1987).

It seems that the presence of vector snails is inevitable in fish culture ponds. In view of this assumption it is interesting to speculate on the relation between *B. truncatus* (the most important vector of urinary schistosomiasis) and water turbidity. If we consider water turbidity under pond conditions as an indicator of the nutritional level of a pond, turbid water having more food available for the fish, then snail control is incompatible with fish culture under optimal conditions. In other words, the risk of having vector snails in ponds increases when quality of nutrition and fish production levels are increased. This is in accordance with the literature where there seems to be consensus that food availability is one of the crucial factors determining population densities of snails (Brown 1980).

Taking these considerations into account, evidently one should strongly oppose the introduction of communal village fish ponds in schistosomiasis prone areas, unless measures are taken to fence the ponds from the villagers (especially children). It is recommended to include a health assessment in the planning phase of an aquaculture development project, because with proper measures centred around prevention of snails becoming infected and reduction of water contacts, the risk of schistosomiasis transmission can be minimized.

References

Bard J. & Mvogo L. (1963) Note d'information sur l'*Astatoreochromis alluaudi* poisson malacophage utilisable dans la prophylaxie de la bilharziose. *Bulletin de la Société de Pathologie Exotique* **56,** 119–126.

Berrie A.D. (1966) Fish ponds in relation to the transmission of bilharziasis in East Africa. *East African Agriculture and Forestry Journal* **31,** 276–281.

Brown D.S. (1980) In: *Freshwater Snails of Africa, and their Medical Importance.* Taylor & Francis Ltd., London.

Coates D. (1984) A survey of the fish fauna of Sudanese irrigation systems with reference to the use of fishes in the management of ecological problems (the control of aquatic weeds, malaria and infective schistosomiasis). *Fisheries Management* **15,** 81–96.

Kat P. & Kibberenge M. (1990) An evaluation of biological control of snail intermediate hosts of schistosomiasis by the molluscivorous fish *Astatoreochromis alluaudi. Utafiti* **3,** 6–12.

McMahon J.P. (1960) Preliminary observations of the control by fish of snails and mosquitos in dams. *Annual Reports of the East African Fisheries Organisation, Jinja, Uganda:* Appendix "K", pp. 41–46.

McMahon J.P., Highton R.B. & Marchall T.F. de C. (1977) Studies on biological control of intermediate hosts of schistosomiasis in Western Kenya. *Environmental Conservation* **4,** 285–289.

Mvogo L. & Bard J. (1964) Séconde note d'information sur l'*Astatoreochromis alluaudi* poisson malacophage utilisable dans la prophylaxie de la bilharziose. *Bulletin de la Société de Pathologie Exotique* **57,** 21–23.

Siegel S. & Castellan N.J. (1988) *Nonparametric Statistics for the Behavioural Sciences,* 2nd edn. McGraw-Hill International Editions, New York.

Slootweg R. (1987) Prey selection by molluscivorous cichlids foraging on a schistosomiasis vector snail *Biomphalaria glabrata. Oecologia* **74,** 193–202.

Slootweg R. (1989) Proposed introduction of *Astatoreochromis alluaudi*, an East African mollusc crushing cichlid, as a means of snail control. *Musée Royal de l'Afrique Centrale, Annales des Sciences Zoologiques* **257,** 61–64.

Slootweg R. (1991) Water resources management and health: general remarks and a case study from Cameroon. *Landscape and Urban Planning* **20,** 111–114.