al. (1977), this corresponds to a total of around 3145 infective bites which is bracketed by the range of previous estimates. The model also has several implications for the performance of vector control strategies. In particular, the fact that the rise in mf prevalence in children depends only on the average level of transmission scaled by age, allows us to model the eventual equilibrium effects of constant levels of vector control. Fig. 3 illustrates the application of this simple model, and portrays the change expected at equilibrium to the pre-control age-prevalence curve as a result of a 40 % reduction in ITv [as occurred in the IVM area over the 8-year period from 1982 to 1989 (Fig. 1)]. The result indicates that vector control alone may have little impact on the overall age-prevalence of infection even when sustained for long periods. These results are crude and, for instance, ignore spatial heterogeneities and the likely effects of acquired immunity in adults. The present work, however, provides an initial framework for assessing the impacts of these processes in the overall transmission dynamics and control of filariasis.

REFERENCES

Das P.K., Manoharan A., Subramanian S., Ramaiah K.D., Pani S.P., Rajavel A.R. & Rajagopalan P.K. : Bancroftian filariasis in Pondicherry, South India – epidemiologic impact of recovery of the vector population. *Epidemiology and Infection*, 1992, *108*, 483-493.

Hairston N.G. & Jachowski L.A. Analysis of the *Wuchereria bancrofti* population in the people of American Samoa. *Bulletin of the World Health Organization*, 1968, *38*, 29-69.

Rajagopalan P.K., Kazmi S.J. & Mani T.R. : Some aspects of transmission of *Wuchereria bancrofti* and ecology of the vector *Culex pipiens fatigans* in Pondicherry. *Indian Journal of Medical Research*, 1977, *66*, 200-215.

Ramaiah K.D. & Das P.K. : Seasonality of adult *Culex quinquefasciatus* and transmission of bancroftian filariasis in Pondicherry, South India. *Acta Tropica*, 1992, *50*, 275-283.

Subramanian S., Pani S.P., Das P.K. & Rajagopalan P.K. : Bancroftian filariasis in Pondicherry, South India : 2. Epidemiological evaluation of the effect of vector control. *Epidemiology and Infection*, 1989, *103*, 693-702.

Vanamail P., Subramanian S., Das P.K., Pani S.P., Rajagopalan P.K., Bundy D.A.P. & Grenfell B.T. : Estimation of age-specific rates of acquisition and loss of *Wuchereria bancrofti* infection. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 1989, *83*, 689-693.

13

CATTLE, WORMS AND ZOOPROPHYLAXIS

RENZ, A.*, ENYONG P.** & WAHL G.***

KEY WORDS : onchocerciasis. crossprotective immunity. zooprophylaxis. epidemiology. mathematical model. Cameroon.

Summary

Epidemiological studies in North Cameroon indicate that a high population density of cattle in relation to man protects from severe onchocerciasis. In the following, we present a mathematical model which allows to study the effects of zoophily of the vectors, of concomitant immunity in the human population and of cross-protective immunity caused by the infective larvae of a bovine parasite, *Onchocerca ochengi*, inoculated into man by *Simulium damnosum* s.l. Besides this influence on onchocerciasis, cattle also play a major role in the epidemiology of malaria (zooprophylaxis through vector dilution) and schistosomiasis (protection by crossreactive concomitant immunity).

*Fachgebiet Parasitologie, Universität Hohenheim, Emil-Wolf-Strasse 34, 70599 Stuttgart, Germany.

** Medical Research Station, P.O. Box 55, Kumba, Cameroon.

*** Institut für Tropenmedizin, Wilhelmstrasse 27, 72074 Tübingen, Germany.

INTRODUCTION

In many traditional African societies, cattle are a sign of richness and welfare. There is also increasing evidence that cattle protect from some of the most dangerous parasitic diseases. Either by diverting the vectors coming to take a bloodmeal or by the transmission of bovine parasites to man which do not develop but stimulate the immune system. The reduction of the vectorial capacity of bloodfeeding vectors has been called "zooprophylaxis", whilst the latter, i.e. resistance against the human parasite caused by cross-reactive immunity, was named the "Jennerian principle of zooprophylaxis" (Nelson, 1987). In the following, the role of cattle will be examined with view to the epidemiology of human onchocerciasis, with a brief outlook on its influence on malaria and schistosomiasis, which are usually co-endemic in the same regions.

A MATHEMATICAL MODEL FOR ONCHOCERCIASIS

A stochastic model has been derived from the formulae given in Dietz (1982). It allows to plot the average worm load in the human population (adult worms or microfilariae in the skin) in dependence from the size of the vector populations (m) and their biting rate on man (h, proportion of bloodmeals on the human host). In Figure 1, the effect of bloodfeeding on animals (zoophily) alone is considered, whilst in Figure 2, the probability of an infective larvae of *O. volvulus* to reach maturity in the human host is reduced by 90 %. Such a reduction could either stem from crossprotective immunity caused by *O. ochengi* L3 or from a vaccination programme.

Even at moderate levels of cross-protection (50 % reduction) and bloodfeeding on non-human hosts (50 % of all bloodmeals) the treshold level for endemicity, below which onchocerciasis cannot maintain itself, increases from an Annual Biting rate of 200 flies per man and year (if all flies fed on man and there is no immunity) to 1 500 flies per man and year. However, the protection by immunity would have to achieve or even surpass 99,9 % to eradicate onchocerciasis under the worst conditions, i.e. at places as observed in the Cameroon rain forest, where the Annual Biting Rate at the river is as high as 600 000 *Simulium damnosum* s.l. per man and year (Duke et al., 1972) and where almost all flies fed on the human population.

Whilst our model predicts that an increase in the proportion of bloodmeals and animals (cattle) is very unlikely to increase transmission of human onchocerciasis (for example by an increase of the fly-population due to better survival and/or fecundity), and this is supported by our field data, the situation may be different with regard to the transmission of malaria by Anopheles.

Zooprophylaxis

Here, an increase in the number of blood-host could enhance malaria transmission, in case the availability of a bloodmeal is a limiting factor for the fly-population. There is no Plasmodium species from cattle that could afford protection by vaccination. In contrast to onchocerciasis, where severe infection is a result of the accumulation of many worms over 10 years, in malaria, a single infective bite can lead to the full clinical picture. Applying to model analyses of the effectiveness of zooprophylaxis in malaria control by Sota & Mopti (1989) to the local conditions in North-Cameroon, it would however appear that the high number of cattle in the Adamawa highland (5 times more cattle than men) can only reduce the malaria infection rate in the human population, but the extend of this protection remains yet undetermined.

Cross-resistance in Schistosomiasis

Convincing examples of cross-protective immunity come from field observations and from experimental schistosomiasis in cattle and baboons (Taylor *et al.*, 1991). In areas like Sardinia, Corsica and Sicily where *Schistosoma bovis* occurs in cattle, there was no *S. haematobium* in man, despite a highly susceptible population of *Bulinus truncatus*. In baboons, exposed to cercariae of *S. bovis*, protection could be achieved against a challenge infection with *S. haematobium*, but this protection was less marked with *S. mansoni* and it was suggested that the degree of heterologous immunity was related to the phylogenetic closeness between the *Schistosoma* species involved (loc. cit.). Although no detailed study has yet been carried out, it seems possible, that the low prevalence of *S. haematobium* (but not of *S. mansoni* !) in the Adamawa highland (Ratard *et al.*, 1990) might be due to such crossprotective immunity. Bovine schistosomiasis (*S. bovis)* and *Trichobilharzia* species in birds are very common there.

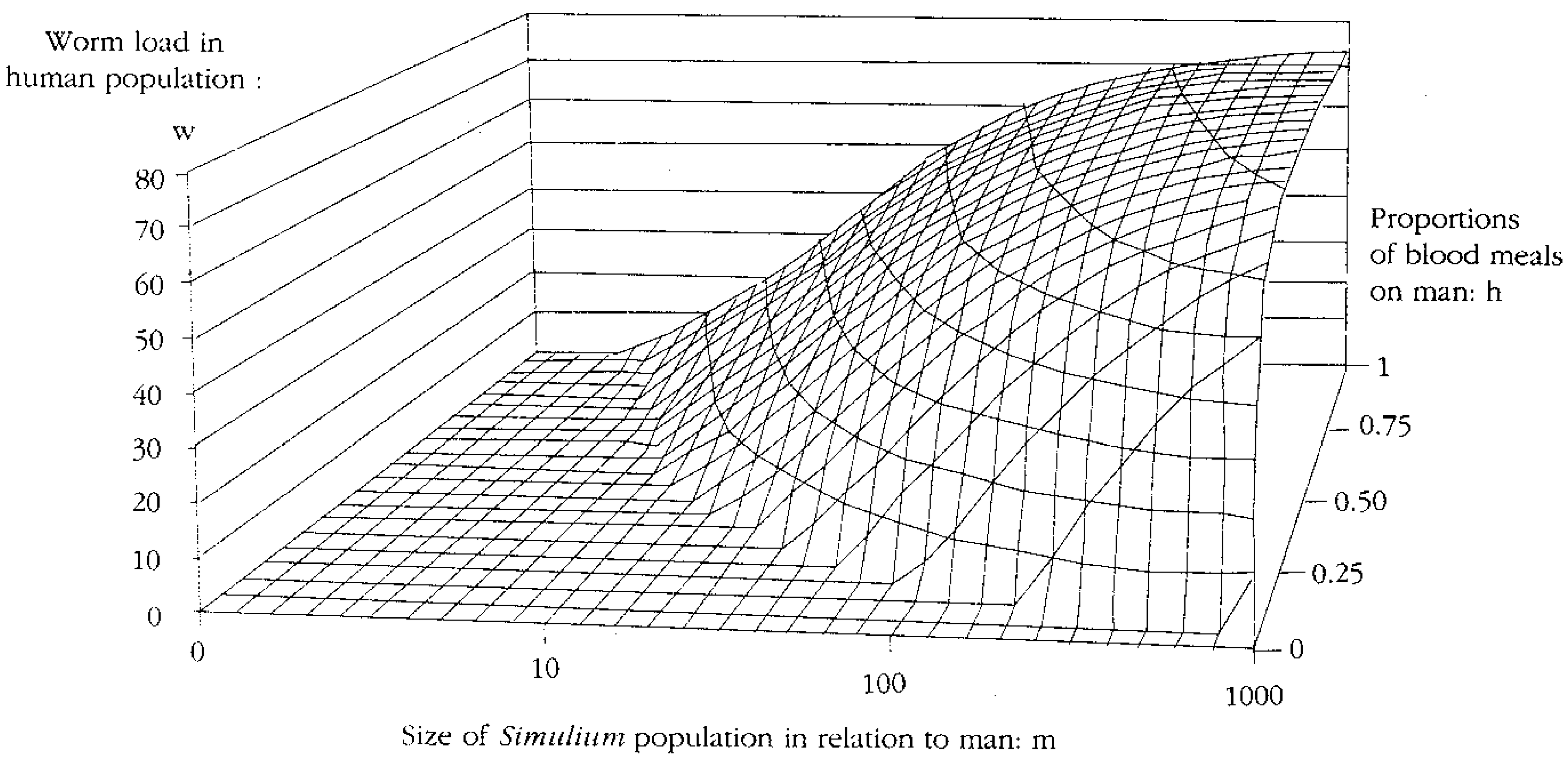

Fig. 1. – Relation between the worm load in the human population (w, microfilariae per skin biopsy), the size of the *Simulium* vector population in relation to the human population (m, flies per man) and the proportion of bloodmeals taken from the human population (h). The Annual Biting Rate of the flies on man can be calculated by multiplying m with the average number of bloodmeals taken per day from the human population (1/3.5xh) and the number of days per year (365).

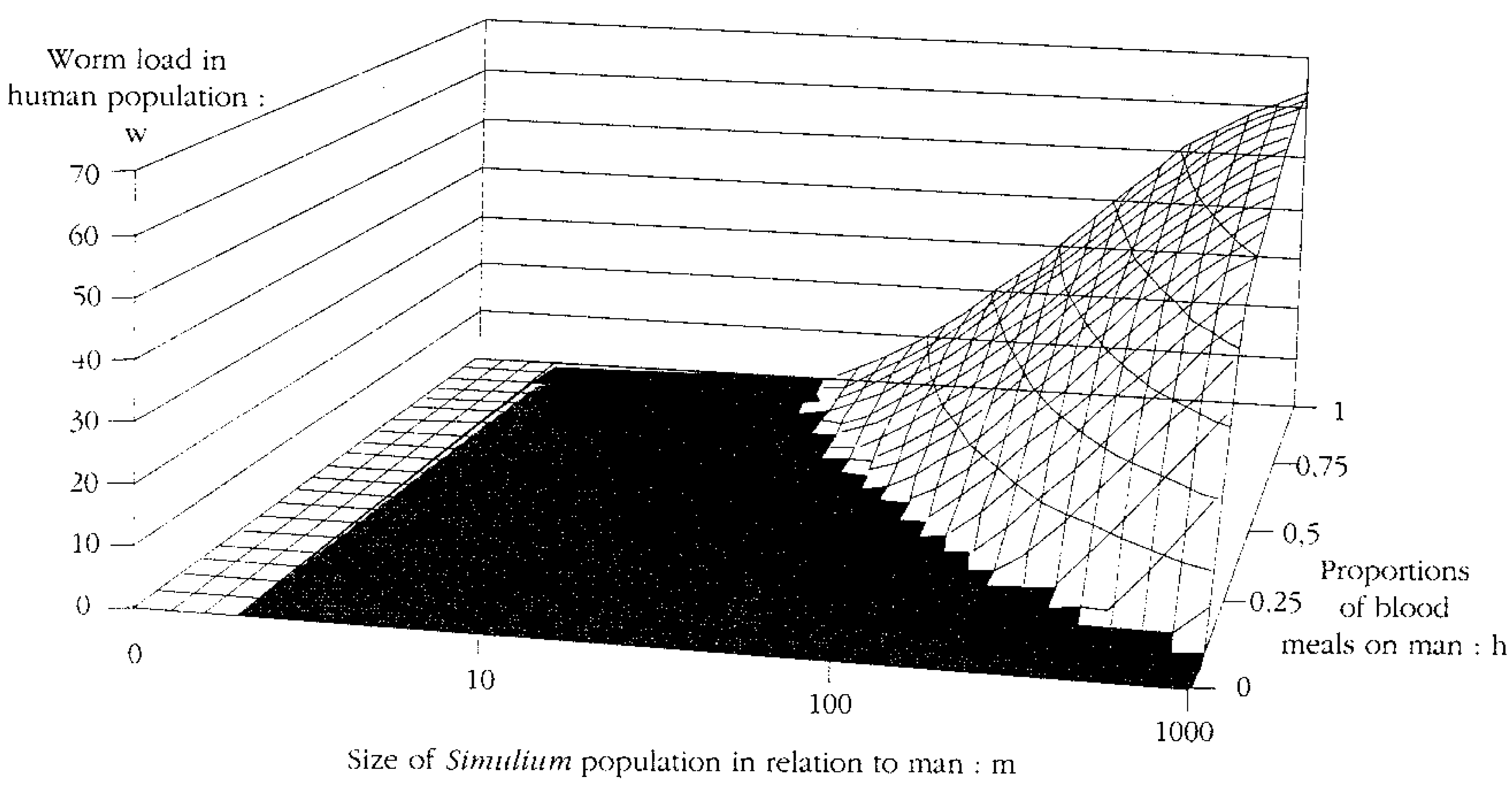

Fig. 2. – Reduction in endemicity of onchocerciasis, if the chance of an infective larvae to reach maturity is reduced by the factor 10, either by crossprotective immunity or by vaccination with an anti-L3 vaccine. The dotted area delimits treshold values of m and h, below which onchocerciasis cannot be endemic and the black area shows the additional gain by a vaccine achieving 90 % reduction. The proportion of infective larvae found in the flies that develop to maturity, prior to density-dependent regulation, is set to 0.0625 in Fig. 1 (50 % of larvae leave the fly during the bloodmeal, 50 % penetrate the skin and 25 % develop to the adult stage) and 0.00625 in Fig. 2.

CONCLUSION

As more results from our ongoing studies in Cameroon and Nigeria become available, modifications and better adjustments of our model will be made. Rapid socio-economic, ecological and cultural changes in rural areas of Africa influence the epidemiology of the major parasitic diseases in various ways. Some conclusions and recommendations may already be drawn from our work on onchocerciasis :

– In the Cameroon Sudan savanna, where severe blinding onchocerciasis is hyperendemic, nomadic Bororo herdsmen nowadays increasingly come with their cattle into the riverine areas during the dry season, when the contrast between human and fly-population is closest, thus introducing a considerable effect of zooprophylaxis.
– Keeping cattle throughout the year at strategic site between the village and the *Simulium* breeding river should afford the highest degree of protection.
– The proportion of bloodmeals on the human population is very low at present (10 to 30 %). Individual protection from the bites of the flies must therefore not necessarily increase the risk for the non-protected part of the population, but on the other hand, the vectorial capacity of the local flies could increase considerably, if the availability of animal bloodhosts decreases or if the density of the human population increases.
– The reservoir of *O. ochengi* in cattle could possibly be affected by anthelmintic treatment of cattle. Acaricide treatments (pour-on) repel biting *Simulium* flies thus increasing the proportion of bloodmeals on the human population and reducing the vaccination effect.
– Mass distribution of ivermectin for treatment of human onchocerciasis will enhance the protective effects of *O. ochengi* L3 by reducing the proportion of *O. volvulus* L3 in the flies.

Our present field-studies concentrate on the influence of cattle on the epidemiology of human onchocerciasis, but the way in which domestic animals influence other parasitoses should also be considered. Investigations on the epidemiological links between onchocerciasis, schistosomiasis and malaria are therefore suggested.

REFERENCES

Dietz K. : The population dynamics of onchocerciasis. In : The population dynamics of infectious diseases : theory and applications. R.M. Anderson ed. Chapman and Hall, London & New York, 1982, 209-241.

Duke B.O.L., Moore P.J. & Anderson J. : A comparison of the *Onchocerca volvulus* transmission potentials of *Simulium damnosum* populations in four Cameroon rain-forest villages and the pattern of onchocerciasis associated therewith. *Ann. Trop. Med. Parasitol.*, 1972, *66*, 219-234.

Nelson G. : Parasitic zoonoses. In : The biology of parasitism : a molecular and immunological approach. P.T. Englund and A. Sher (eds). New York : Alan R. Liss, *MBL lectures in Biology*, 1988, *9*, 13-41.

Ratard C. *et al.* : Human schistosomiasis in Cameroon. I. Distribution of schistosomiasis. *Am. J. Trop. Med. Hyg.*, 1990, *42*, 561-572.

Sota M.G. & Mogi M. : Effectiveness of zooprophylaxis in malaria control : a theoretical inquiry, with a model for mosquito populations with two bloodmeal hosts. *Med. Vet. Entomol.*, 1989, *3*, 337-345.

Taylor M.G., Hussein M.F. & Harrison R.A. : Baboons, bovine and bilharzia vaccines. In :Parasitic helminths and zoonoses in Africa. C.N.L. Macpherson and P.S Craig (eds), London : Unwin Hyman, 1991, 237-259.

ONCHOCERCIASIS IN GUINEA BISSAU, WEST AFRICA

SANTOS GRACIO A.J.*, SHELLEY A.J.**, CHARALAMBOUS M.**, LOWRY C.A.**, GRACIO M.A.A.*, FORTE J.A.G.*, RAYBOULD J.**, MOLYNEUX D.*** AND NHAQUE A.T.****

KEY WORDS : onchocerciasis. simuliidae. Guinea Bissau

INTRODUCTION

Guinea Bissau is a small country in West Africa with a population of about one million (130,000 in villages along the Geba river and 120,000 along the Corubal river). The country is divided into coastal lowlands of mangrove swamps, a high (200 m) plateau and hilly area in the south east and a lowland plateau area below 100 m altitude in the north east. The country is drained by four main rivers : the Geba, Corubal, Mansoa and Cacheu. The climate is characterised by a hot and rainy season from June to October and a dry season from November to May with annual rainfall varying between 1200 to 2750 mm and temperatures from 26° to 29° C. The vegetation in the north east of the country is a mosaic of woodland and Sudan-Guinea savanna.

Human onchocerciasis in Guinea Bissau was first recorded in 1956 by Lecuona at Paina Lenguer-Piche (close to the Corubal river). Later word (Lecuona, 1959) showed a prevalence rate of 14.8 % in 2,585 persons examined at villages along the Corubal and Geba rivers and *Simulium damnosum* s.l. was found naturally infected with filariae at two localities on the Corubal river. In 1960 Lecuona presented a review of onchocerciasis and new data for the Sonaco region (Geba river) where he found *Simulium damnosum* s.l. Later, Tendeiro (1963) carried out an entomological survey and found ten species of blackflies in the Geba and Corubal rivers : *Simulium damnosum* s.l., *S. alcocki*, *S. garmsi* (= *S. occidentale*), *S. diallonense*, *S. cervicornutum*, *S. unicornutum*, *S. ruficorne*, *S. adersi* and *S. hargreavesi*. Most recently Abreu (1964) examined 482 persons and found 61.2 % positive for onchocerciasis in the Gabú region near the Corubal river and in 1965 found the same species of simuliids in the Corubal river as Tendeiro (1963).

PARASITE PREVALENCE RATES

Using weighed skin snips the prevalence of onchocerciasis in Guinea Bissau was recorded between 1989 and 1993. Villages along the rivers Geba and Corubal were

* Instituto de Higiene e Medicina Tropical (Universidade Nova de Lisboa), Rua da Junqueira, 96 – 1300 Lisboa, Portugal.
** Medical and Veterinary Division, Entomology Department, The Natural History Museum, Cromwell Road, London SW7 5BD, U.K.
*** Liverpool School of Tropical Medicine (formerly University of Salford), Pembroke Place, Liverpool L3 5QA, U.K.
**** Centro de Medicina Tropical da Guiné-Bissau, Guinea Bissau.