Bongers T. (1999) The maturity index, the evolution of nematode life history traits, adaptive radiation and cp-scaling. Plant and Soil 212:13-22.
Bongers, T. & H. Ferris (1999) Nematode community structure as a bioindicator in environmental monitoring. TREE, 14, 224-228.
Ferris, H, T Bongers & RGM de Goede (2001) A framework for soil food web diagnostics: extension of the nematode faunal analysis concept. Appl. Soil Ecol., 18, 13-29.
Oostenbrink, M. (1960) Estimating nematode populations by some selected methods. In: J.N. Sasser & W.R. Jenkins eds., Nematology. University of North Carolina Press, Chapel Hill, NC, pp. 85-102.
Rutgers M and J. Bogte (2002). Rubble, pipe bowls, ceramic fragments and what more in Toemaakdek in De Venen? SSEO-issue 5:8-12
Trett, M.W., B. Calvo Urbano, S.J. Foster, J.D. Hutchinson, R.L. Feil, S.P. Trett and J.G. Best (2000) Terrestrial meiofauna and contaminated land assessment. Envir. Sci. Technol. 34:1594-1602.
Van Straalen, N.M. (1998) Evaluation of bioindicator systems derived from soil arthropod communities. Appl. Soil Ecol. 9:429-437.
Yeates, G. W., Bongers, T., De Goede, R. G. M., Freckman, D. W., and Georgieva, S. S. (1993). Feeding-Habits in Soil Nematode Families and Genera - an Outline for Soil Ecologists. J. Nematol. 25, 315-331

Insights from integrating field data with population models.

Chris Klok
ALTERRA, Research Institute for our green living environment, Postbus 47, 6700 AA Wageningen.
Chris.Klok@wur.nl

Introduction

One of the objectives of the SSEO programme is to '*to apply the accumulated knowledge to help formulate and put in place environmental policies concerning chronic and diffuse exposure of the environment to mixtures of toxic compounds'*. This objective is embedded in the validation and toolbox project of Posthuma, Traas, Klok, van de Brink, and Hendriks, which aims at integrating SSEO data with existing modelling tools. One of the ongoing cooperation activities was initiated by Mathilde Zorn. This concerns the question to what extent pollutants present in frequently inundated river flood plains reduce the population viability of earthworms The resulting paper is summarised below.

Maintaining viable earthworm populations in river flood plains. Does plasticity in maturation in Lumbricus rubellus promote population survival?

Chris Klok (Alterra), Mathilde Zorn (VU), and Josée Koolhaas(VU)

The soils of river flood plains are among the most fertile on earth as a direct result of the frequent inundation. Soil invertebrates such as earthworms can reach high densities in these fertile soils. However, these areas are frequently polluted and, to maintain viable populations, earthworms must cope with the stress induced by both pollution and frequent flooding. Zorn *et al.* (in prep) found that, after an inundation period, all life stages of *Lumbricus rubellus* were virtually absent, with the exception of cocoons. Cocoons can survive and even hatch under water. Population recovery most probably results from these cocoons, since dispersal rates are very low in *L. rubellus*. If population recovery in *L. rubellus* is created primarily by individuals that were in the cocoon stage at the moment the flood plain was flooded, the timing of the inundation, the period between subsequent indundations and the duration of the period the river flood plain remains dry become important. If inundations occur repeatedly and none of the dry periods is long enough for individuals to grow from cocoons to adults, recovery will certainly be disrupted.

This paper analyses the link between inundation regime, timing of these inundations and duration of the periods the river flood plain remains dry, and the maturation and population viability in *L. rubellus*. We assumed that the duration of the dry period is crucial for the viability of

L. rubellus populations in river flood plains, and that local populations are adapted to the current inundation regime resulting from plasticity in maturation. Field data on maturation weight of earthworms living in areas with different inundation regimes, sampled at a frequently inundated site (ADW), at a regularly inundated site (LH) and at a rarely inundated site (PPO) were compared. All three sites are moderately polluted with heavy metals. The distribution of the periods the flood plains remain dry in each of these areas was determined from site-specific data and water levels over a reference period of 15 years. The critical dry period, critical in the sense that populations cannot survive if the dry period is shorter, was assessed using a deterministic population model based on the model developed by Klok & de Roos (1996). A stochastic version of this model was used to assess population survival probability under environmental stochasticity resulting from variations in the duration of dry periods.

The results indicate that the weight of juveniles, sub-adults and adult specimens of *L. rubellus* that were sampled at the frequently inundated site was significantly lower than that of the specimens from the other two sample sites (Table 1). Moreover, the mean weight of adults at the ADW site was significantly lower than the mean weight of sub-adults at the other two sites (ANOVA $p<0.01$), which indicates that the weight of maturation at ADW is not only lower than the respective weights at the other sites, but even lower than the sub-adult weights at these sites.

Table 1: Individual weights of sampled L. rubellus individuals in the three stage classes in gram fresh weight sampled in April. Different letters in a column indicate significant differences between weights (p=0.05 Bonferroni test).

	juvenile			subadult			adult		
site	mean	sd	n	mean	sd	n	mean	sd	n
ADW	0.161^{A}	0.084	13	0.320^{A}	0.100	6	0.504^{A}	0.185	22
LH	0.281^{B}	0.169	31	0.627^{B}	0.085	6	0.714^{B}	0.209	16
PPO	0.384^{B}	0.193	24	0.761^{B}	0.158	4	0.972^{C}	0.301	24

The deterministic model results (Fig. 1, left panel) indicate that the critical dry period decreases with a decrease in maturation weight. When age-dependent mortality increases as a result of predation, regional pollution, maturation weight or the duration between two inundation periods, the viable population greatly decreases (Fig. 1, right panel).

Figure 2 shows the results of the stochastic model. The frequencies in Fig. 2 are based on 10,000 model simulations, each over a period of 100 years, in which the duration between inundation periods in a year is drawn randomly from the ADW dry period distribution, which is a normal distribution. The figure shows that the survival time of the populations decreases with the maturation weight (see Table 1). This suggests that indeed the populations are adapted to the local inundation regime.

To what extent pollutants reduce population viability in these highly dynamic environments is difficult to assess. The results of this study show that inundation regime greatly affects local populations, even resulting in a reduction in maturation weight, which may mask the effects of pollutants. However, Fig. 1 (right panel) shows that an increase in age-dependent mortality induced by pollutants may drastically reduce the survival probability of populations. Moreover, maturation may be retarded at polluted sites (Klok & de Roos 1996), which results in non-viability in areas where populations could still adapt at sites that are not polluted.

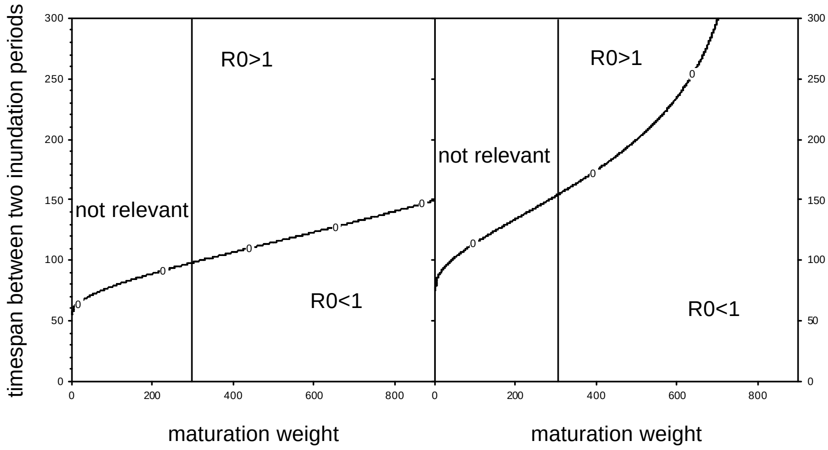

Fig. 1. Parameter space of combinations of maturation weight and time span between two inundation periods indicating where the earthworm population persists. Contour R0 equals 1. Left panel optimal conditions, right panel with increased age-dependent mortality resulting from e.g. pollution.

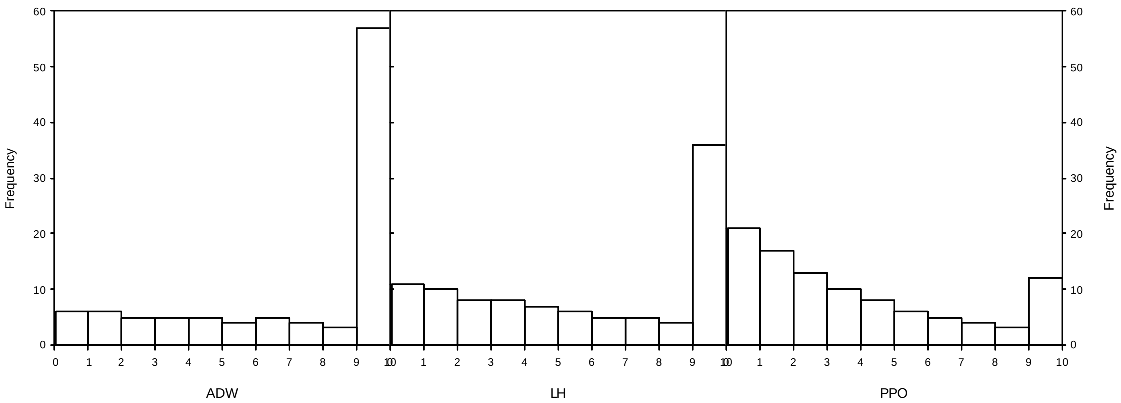

Fig. 2 Frequency distribution of survival times in decades at the three sites, in which the duration of dry periods are drawn randomly from the ADW distribution.

References

Klok C. & A.M. de Roos 1996. Population level consequences of toxicological influences on individual growth and reproduction in *Lumbricus rubellus* (Lumbricidae, Oligochaeta). Ecotoxicology and Environmental Safety 33:118-127.

Zorn, M.I, Van Gestel CAM & Eijsackers H. 2004. Species-specific earthworm population responses in relation to flooding dynamics in a Dutch floodplain soil. (submitted to Pedobiologia)