Topic 2: Introducing a contamination with an insecticide and explore coexistence between two groups of zooplankton that differ regarding their sensitivity to the insecticide.

Introduce an insecticide (e.g. Diazinon) in the inflow to the lake that has sub-lethal effects on the growth of zooplankton. The inflow concentrations have a seasonal pattern according to the application period of the substance (see Fig. 1).

Introduce a second group of zooplankton that has the same composition and processes as the already existing zooplankton group but has a different half-saturation constant regarding food and a different sensitivity to the insecticide (described in more detail below). Note that you have to change the food-limitation term to a Monod-equation instead of a linear dependency. Note that this will change the unit of the parameter k.gro.ZOO from m^3/gALG/d to 1/d.

To model the toxic effect on the growth of both zooplankton groups, you can include a factor f_{tox} in the growth rate (see equation below). This model describes a concentration-effect relationship with a logistic equation. It decreases the growth rate with increasing concentrations of the toxicant (C.T).

$$f_{tox} = \frac{1}{1+\left(\frac{C.T}{EC50}\right)^{slope}}$$

The parameter EC50 determines at which concentration the growth is reduced by 50%. The parameter "slope" determines the slope of the concentration-response curve.

As a rough estimate of the input of Diazinon into the lake with the inflow, you can use the following function:

```
inpPest <- function(t,C.max=10)
{
  xinp <- NULL
  xinp[1] <- 0
  xinp[2] <- strftime("2016-03-01", format = "%j")
  xinp[3] <- strftime("2016-04-01", format = "%j")
  xinp[4] <- strftime("2016-07-01", format = "%j")
  xinp[5] <- strftime("2016-08-01", format = "%j")
  xinp[6] <- 365
  xinp <- as.numeric(xinp)
  yinp <- c(C.max/5,C.max/5,C.max,C.max,C.max/5,C.max/5)
  yout <- approx(x=xinp,y=yinp,xout=t%%365)$y
  return(yout)
}
```

In addition to a time vector, the function only needs one parameter as input, C.max, which describes the inflow concentration of Diazinon during the agricultural application period (April – June) and assumes a concentration of Diazinon of 20% of C.max outside the application period, e.g. from applications in households (Fig. 1). (Note that the default of this parameter is set to 10 here, but it will be overwritten when you call the function with a different parameter value as argument.)

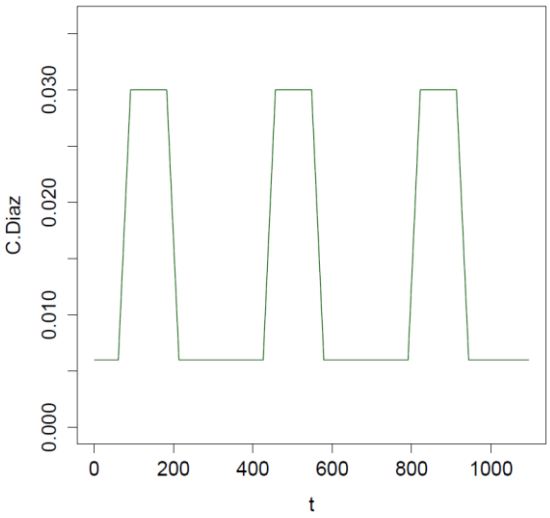

Fig. 1: Diazinon inflow concentrations in µg/L over time, using a C.max of 0.03 µg/L.

Since Diazinon is quite stable under normal temperature and pH conditions, you can neglect here the degradation of the substance[1].

Parameter values:

Try to achieve long-term coexistence (i.e. 3 years or longer) of both zooplankton groups by adjusting the (new) food-limitation parameter and EC50 of the second zooplankton group as follows.

For the slope of the concentration response curve (eqn. 1), you can assume a value of 2.5 for both zooplankton groups. For the EC50, you can assume a value of 0.5 µg/L for one zooplankton group, which is realistic based on short-term exposure experiments in the lab. Assume an EC50 value that is four times lower value for the second group. This value is still approx. ten times higher than the environmental quality standard for Diazinon[1] (12 ng/L) that is considered to be protective.

A realistic C.max for the river discharging into Greifensee would be 0.03 µg/L based on weakly composite samples from 2010. As initial concentration, you can assume 0.006 µg/L, which corresponds to the assumed input concentration outside the agricultural application period. For the half-saturation constant regarding food, you can choose a value 0.5 gDM/m^3 for the less sensitive zooplankton group and a lower value for the more sensitive group. Try to find out, for which parameter value you can achieve long-term coexistence of the two groups.

Finally, think about the most important shortcomings of this model that might lead to differences to what happens in real lakes.

[1] http://www.oekotoxzentrum.ch/expertenservice/qualitaetskriterien/qualitaetskriterienvorschlaege-oekotoxzentrum/, Stoffdatenblatt Diazinon