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INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SMR.780 - 6

FOURTH AUTUMN COURSE ON MATHEMATICAL ECOLOGY

(24 October - 11 November 1994)

"Two-species Interactions, Stage Structure and Environmental Factors"

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Two-species Interactions, Stage Structure and Environmental Factors

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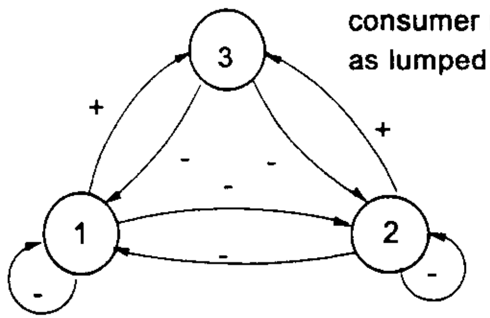
Readings (1 of 2)

- For stage-structured models:
  - Nisbet R.M. and W.S.C. Gurney. 1986. The formulation of Age-Structure Models. pp: 95-115. In: Hallam T.G. and S.A. Levin (Eds.) *Mathematical Ecology: An Introduction*. Springer Verlag, 457 pp.
- For stage-structured models of Daphnia:
  - Nisbet R.M., W.S.C. Gurney, W.W. Murdoch and E. McCauley. 1989. Structured population models: a tool for linking effects at individual and population level. *Biological journal of the Linnean Society* 37:79-99.

Readings (2 of 2)

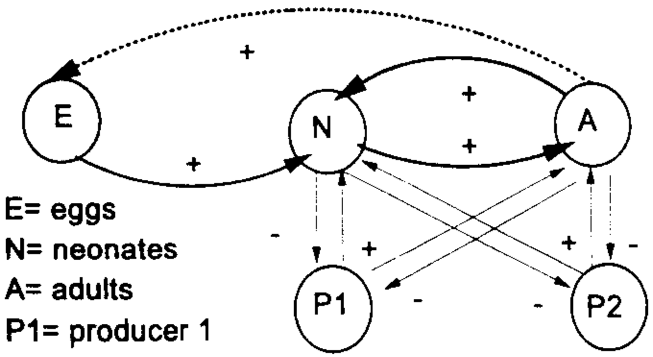
- For ingestion, growth and reproduction:
  - Kooijman S.A.L.M. 1993. DEB in biological systems. Chapter 3. pp 53-113. Cambridge University Press.
- For a recent paper on cladocera:
  - Acevedo M.F., W.T. Waller, D.P. Smith, D. W. Poage and P. B. McIntyre. 1994. Cladoceran population response to stress with particular reference to sexual reproduction. *Non Linear World*. In press.

One consumer - Two producers



Previous lecture: consumer modelled as lumped population

Consumer: 3-Stages
2-Producers: lumped



E= eggs
N= neonates
A= adults
P1= producer 1
P2= producer 2

Modeling methodology

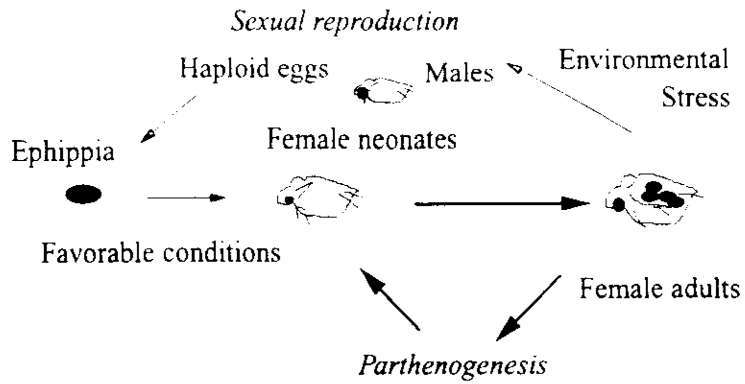
- **Delay-differential equations:**
  - **Nisbet and Gurney methodology**
  - **Size structured population**
- **Process-based sub-models for effects of chemical and physical factors on:**
  - **Recruitment**
  - **Growth**
  - **Mortality**

Why *Ceriodaphnia dubia* ?

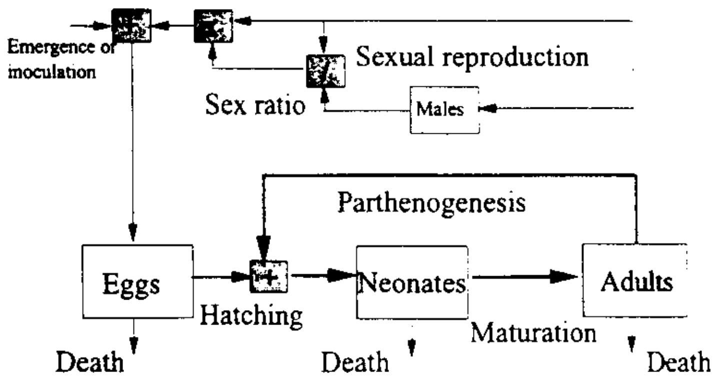
- **life-cycle toxicity tests**
- **representative cladoceran**
- **low level and sub-lethal effects**
- **parthenogenetic and sexual reproductive pathways**

Of course, applicable to other cladocera

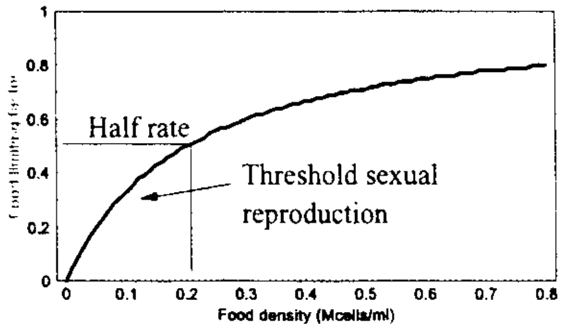
Life-cycle



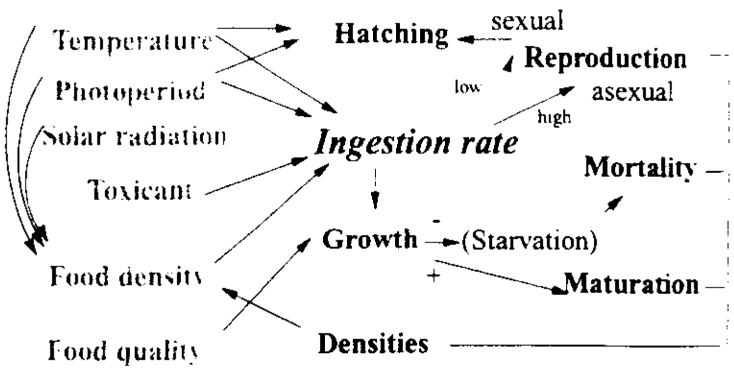
Model Structure: population dynamics



Ingestion rate: food limiting factor



Model Processes: Environmental Controls



Ingestion rate: Environmental controls

Ingestion rate: class i

$$C_i(t) = C_{maxi}\, Qf(t)\, QT(t)\, QP(t)\, QX(t)$$

Food limiting factor: Qf

Environmental limiting factors:

QT = temperature limiting factor
QP = photoperiod limiting factor
QX = stress limiting factor

Growth rate: class i

$$Gi(t) = eff\ Ci(t)\ [\ q_1 a + q_2 (1-a)]$$

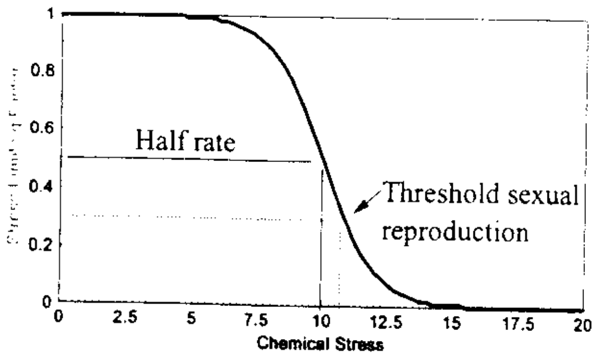
eff = assimilation efficiency
Ci(t) = ingestion rate
q_1 = quality food 1
q_2 = quality food 2
a = fraction of food 1/total

Ingestion rate decreases with toxicant concentration

Experimental evidence:

- **-e.g. Cladocera including** *Ceriodaphnia lacustris*
  K. Day and N.K. Kaushik, 1987.
  Arch. Environ. Contam. Toxicol. **16:423-432.**
- **-recent results with rotifera:**
  C.M. Juchelka and T.W. Snell. Manuscript.

Ingestion rate: stress limiting factor



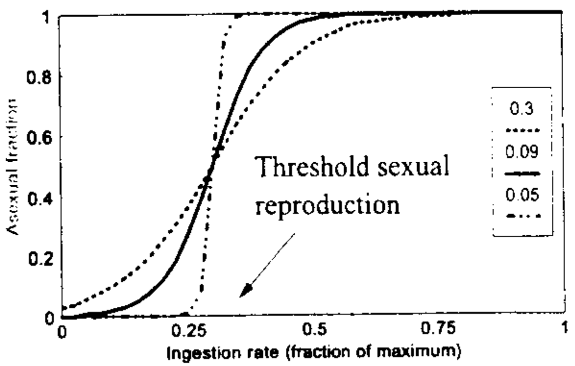
Experimental evidence

Ingestion rate decrease as the stimulus for sexuality in populations of *Moina macrocopa*

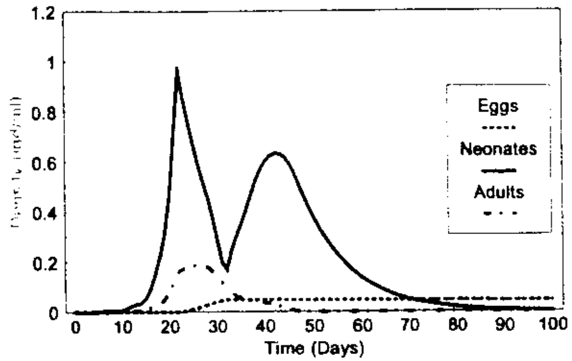
L. R. D'Abramo. 1980. *Limnol.Oceanogr.* **25(3):422-429**

Correlation with particle density
Physical receptors
Threshold at 30 % of maximum rate

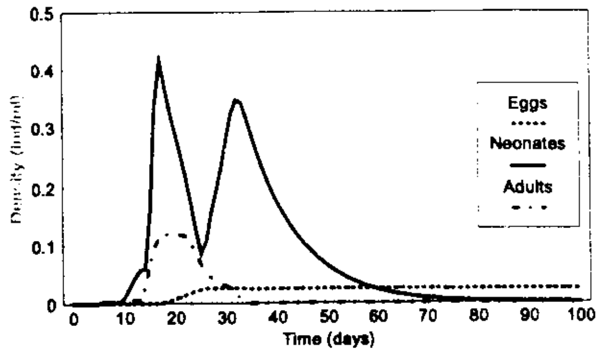
Reproductive Switching Function



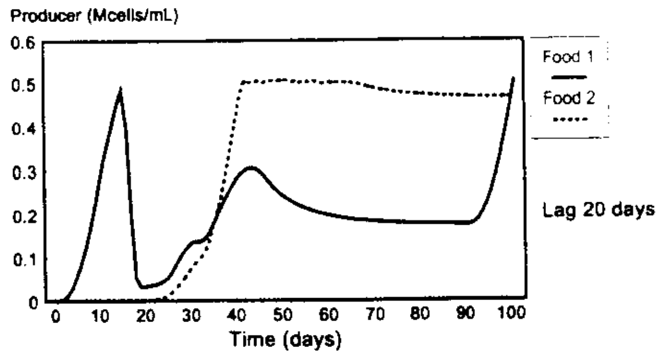
Constant Food Supply Laboratory version



Variable Food Supply Laboratory version



Effect of lag: Lab Version Variable Food Supply



Light limiting factor: Depth averaged

Averaged down to euphotic depth u

QL = {exp(1)/(ku)} { exp[-L(u)/Lop] -exp(-L0/Lop) }

Beer's law:

L(z) = L0 exp(-kz)

Steele's model

P = Pmax [L(z)/Lop] exp[1- L(z)/Lop]

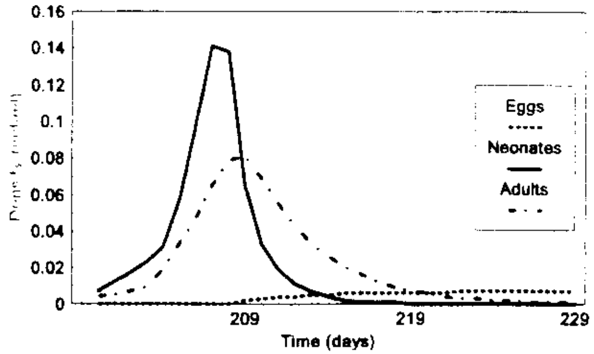
Light extinction factor

k = a + b y(t) + c y(t) ^ 2/3

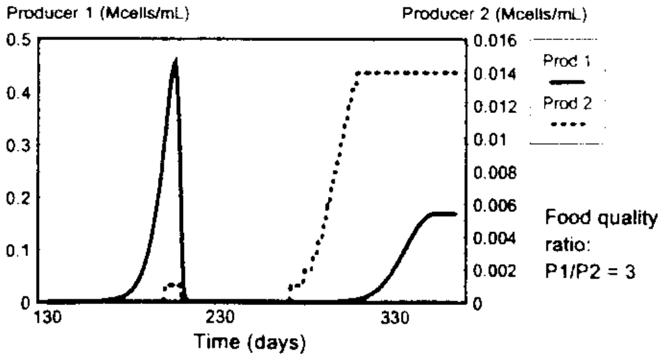
y(t) = P(t) (carbon/chlorophyll)

P(t) = algae density

Field version/ mid latitude



Producer Dynamics: Differential Food Quality, Mid-latitude



Sensitivity and assessments

Endpoints:

maximum values of eggs, neonates, males and adults

Simulations with laboratory version:

-food density controlled by supply:

constant or variable food supply

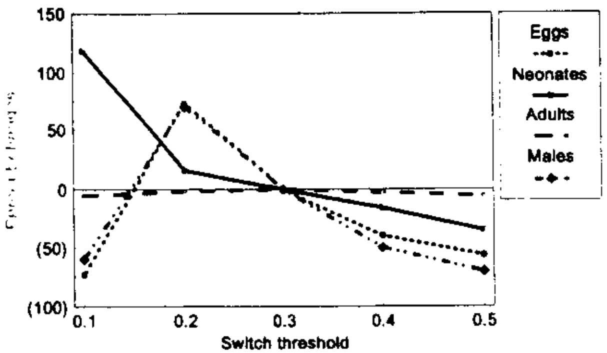
-constant temperature, photoperiod, food quality

Simulations with field version:

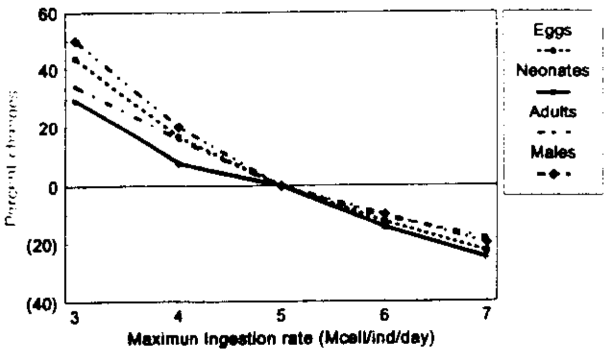
-food density affected by algae population dynamics

-variable temperature, photoperiod, food quality

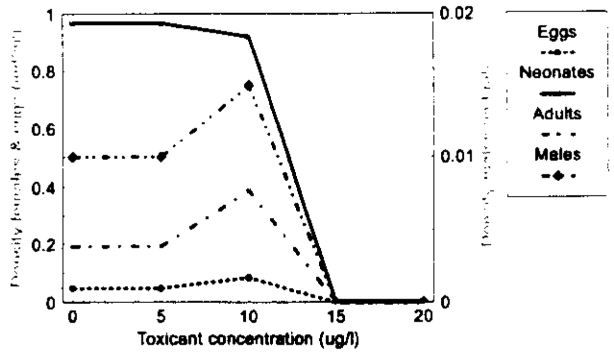
Sensitivity to switch threshold



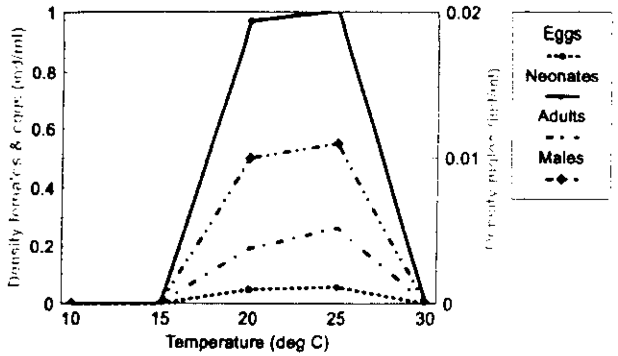
Sensitivity to maximum ingestion rate



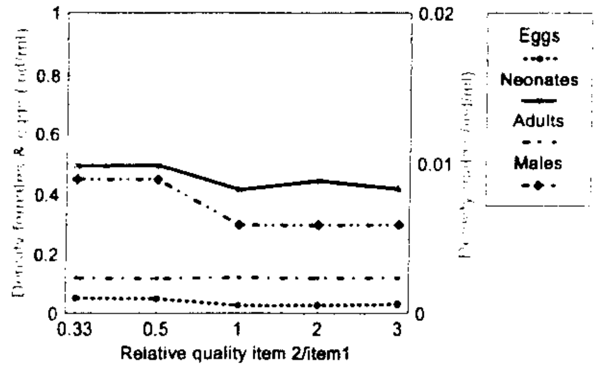
Effects of Toxicant Lab/Const Food/ Equal Quality



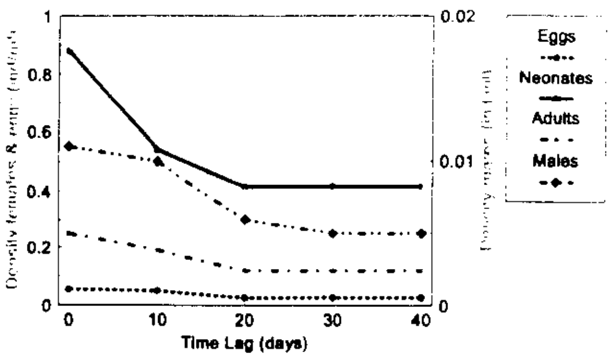
Effects of Temperature
Lab/Const Food/ Equal Quality



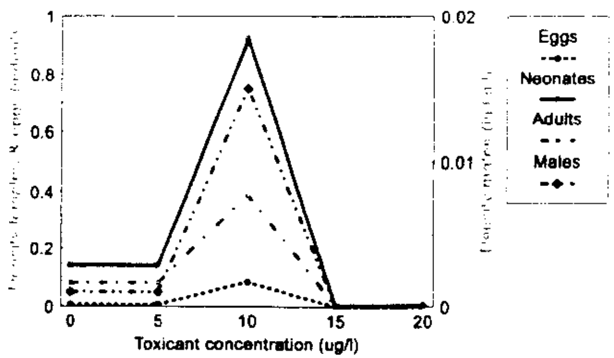
Effects of Food Quality
Lab/ Variable Food



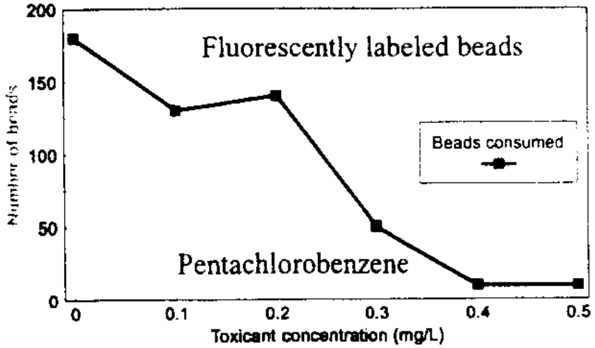
Effects of time lag of food items
Lab/ Var Food/Equal Quality



Effects of toxicant
Field version/Mid latitude



Experimental evaluation: preliminary results



Lecture Summary (1 of 2)

- Importance of structuring the populations in community models
- Life-cycle provides guidance to structure the population models
- Importance of including environmental controls in community models

Lecture Summary (2 of 2)

- Toxicant concentration affects ingestion rate
- Ingestion rate decreases lead to sexual reproduction
- Simulated changes in reproductive mode imply detectable population level responses
- Experimental evaluation
- Potential application to risk assessment
- Potential application to evolutionary demography