Group 3

Group 3

GUERRERO TROYO, Alejandra

MARGARIT, David Hipólito

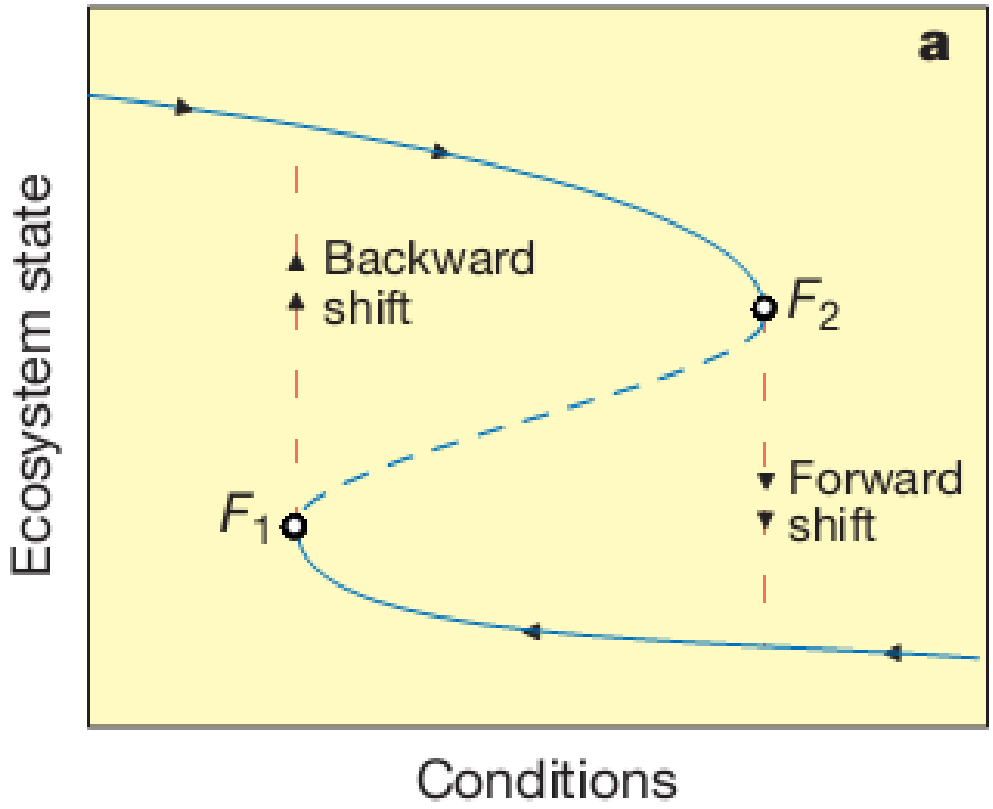
VON HARTENTHAL, Francisco

NAGAI, Micael Eiji

ESPINOZA-PAREDES, Pedro Antonio

Alternative states and hysteresis in shallow lakes

Hysteresis


a
Backward
shift
F_2
F_1
Forward
shift
Ecosystem state
Conditions

ICTP SAIFR

ICTP SAIFR

The study oh hysteresis is important for:

The study oh hysteresis is important for:

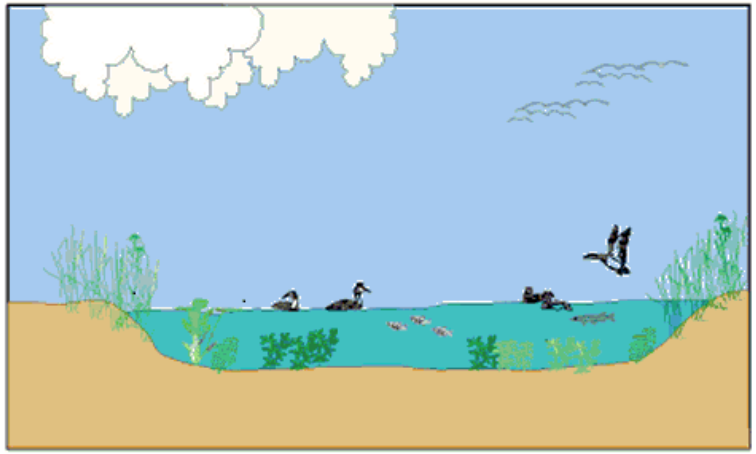
- **Ecological studies**

The study oh hysteresis is important for:

- **Ecological studies**
- **Environmental management**

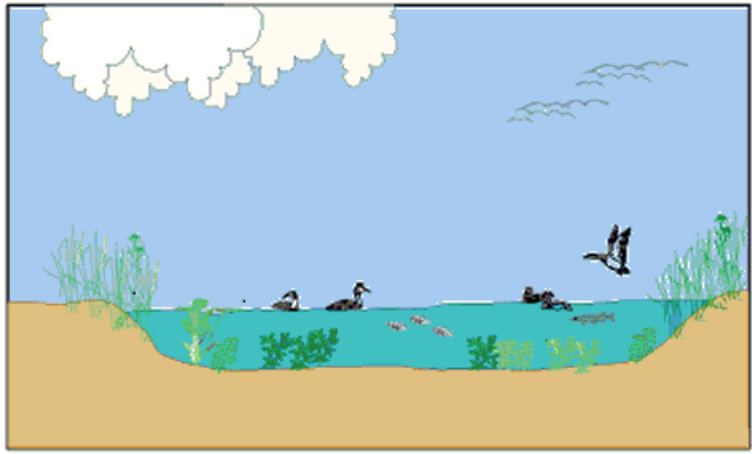
Alternative states in shallow lakes

Alternative states in shallow lakes

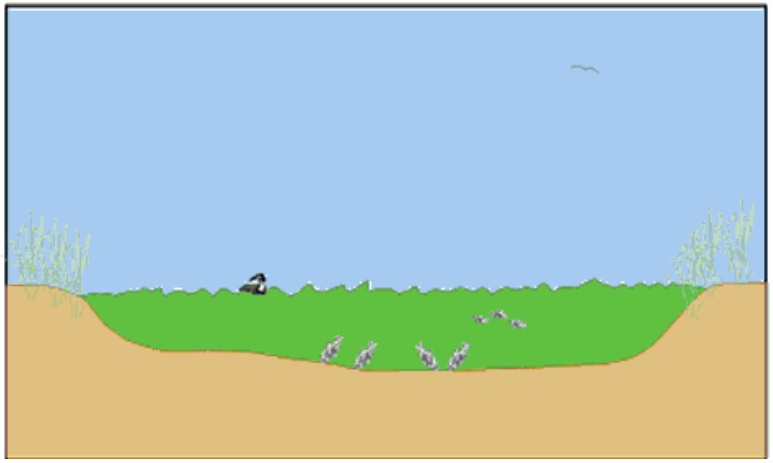


Clear water with abundant submerged vegetation

Alternative states in shallow lakes



Clear water with abundant submerged vegetation



Turbid water with high phytoplankton densities

Our model

Our model

$$\frac{dM}{dt} = r.M(1 - (\frac{M}{k - \frac{k.F.\alpha}{F+1}}))$$

r = growth rate of Macrophyta
α = action of Phytoplankton upon K

ICTP SAIFR

Our model

$$\frac{dM}{dt} = r.M(1 - (\frac{M}{k - \frac{k.F.\alpha}{F+1}}))$$

$$\frac{dN}{dt} = i - d((\frac{M.\beta}{M + m_{dec}}) + 1)N - c.N.F$$

r = growth rate of Macrophyta
α = action of Phytoplankton upon K

i = nutrient input
d = sedimentation rate due to M
c = consuption rate by F

Our model

$$\frac{dM}{dt} = r.M(1 - (\frac{M}{k - \frac{k.F.\alpha}{F+1}}))$$

r = growth rate of Macrophyta
α = action of Phytoplankton upon K

$$\frac{dN}{dt} = i - dN((\frac{M.\beta}{M+1}) + 1) - c.N.F$$

i = nutrient input
d = sedimentation rate due to M
c = consuption rate by F

$$\frac{dF}{dt} = -b.F + e.c.F.N$$

b = mortality rate of F
e = conversion efficiency of F

Note: *N* means only nutrients in suspension

ICTP SAIFR

Dimensionless model

$$\overline{a} = \frac{b}{r}, \overline{p} = \frac{iec}{r}$$

Dimensionless model

$$\overline{a} = \frac{b}{r}, \overline{p} = \frac{iec}{r}$$

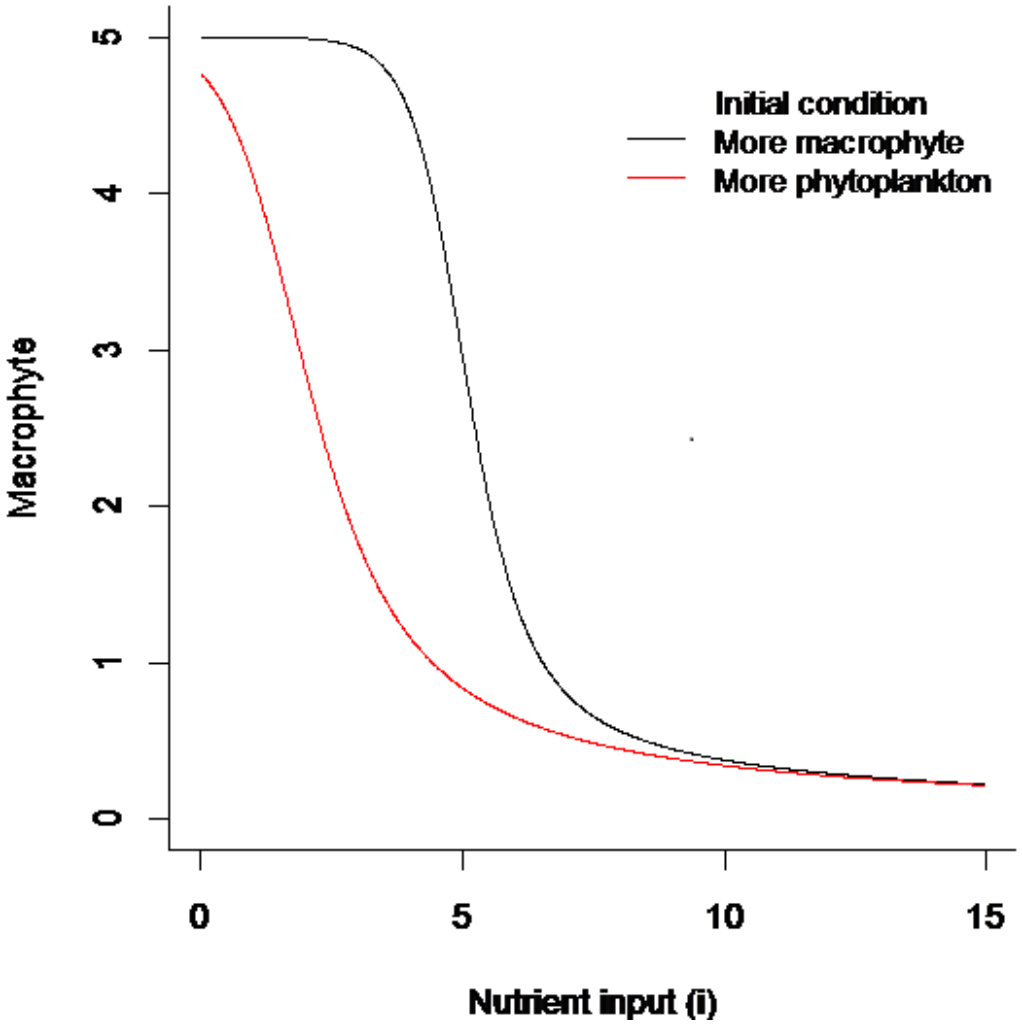
$$\frac{dF}{dt} = -\overline{a}F + FN$$

$$\frac{dN}{dt} = \overline{p} - dN((\frac{M\beta}{M+1}) + 1) - cNF$$

$$\frac{dM}{dt} = M(1 - \frac{M(F+1)}{F(1-\alpha+1)})$$

ICTP SAIFR

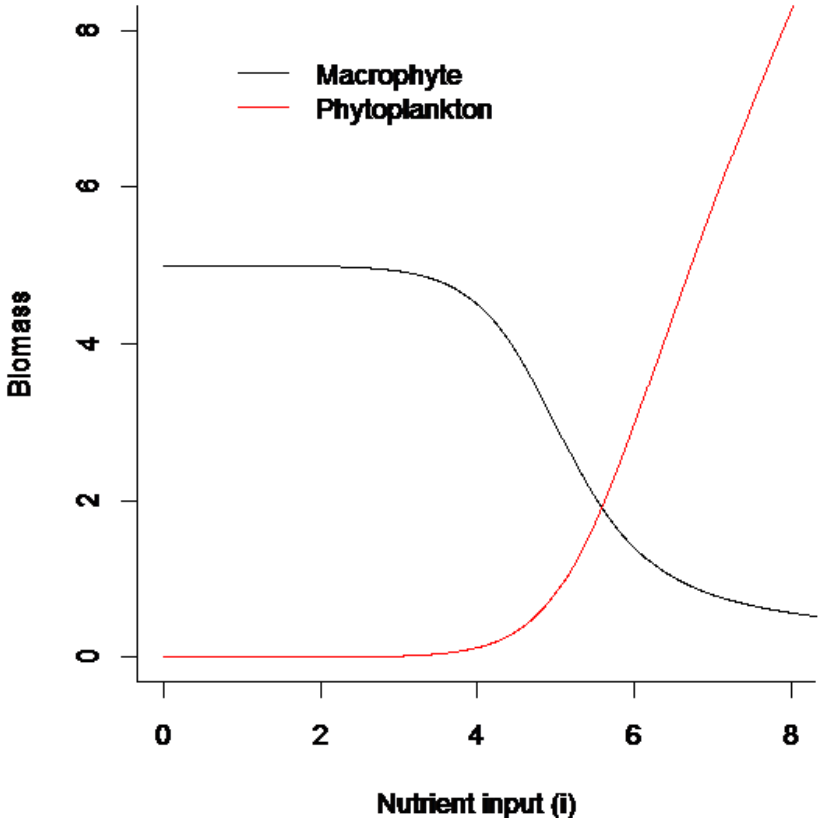
Hysteresis!



ICTP SAIFR

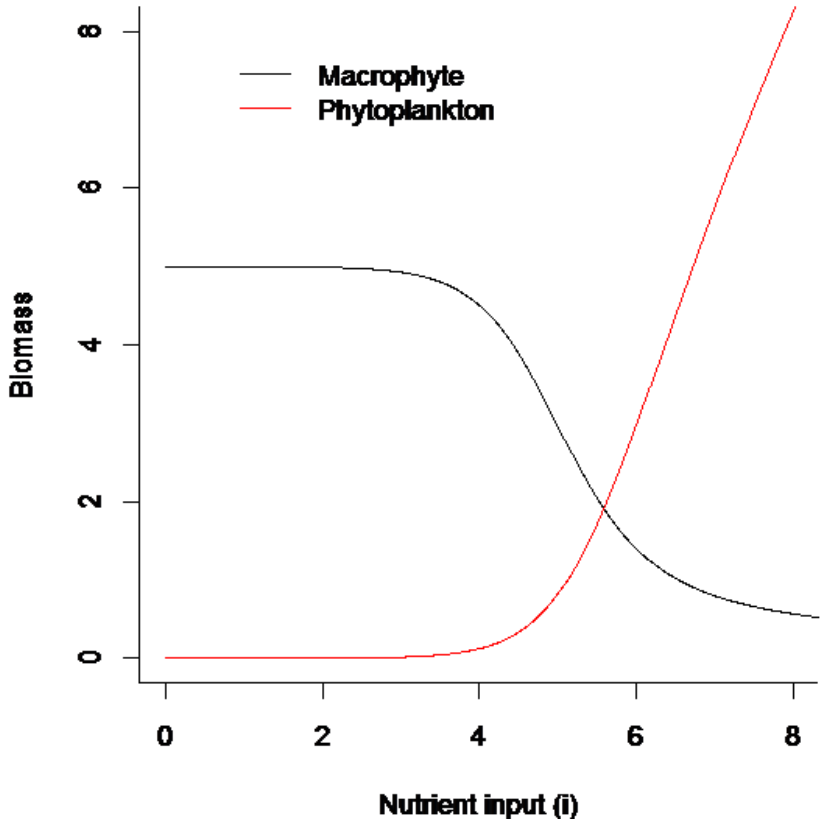
Catastrophic change!

$M_0 >> F_0$

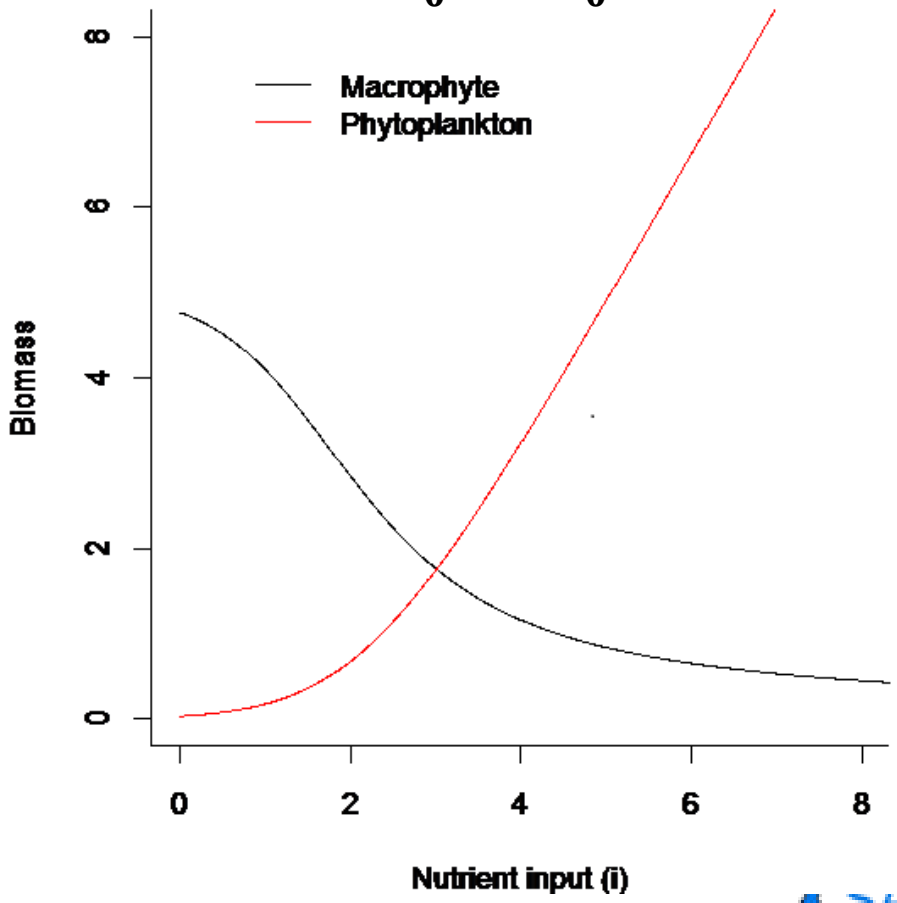


Catastrophic change!

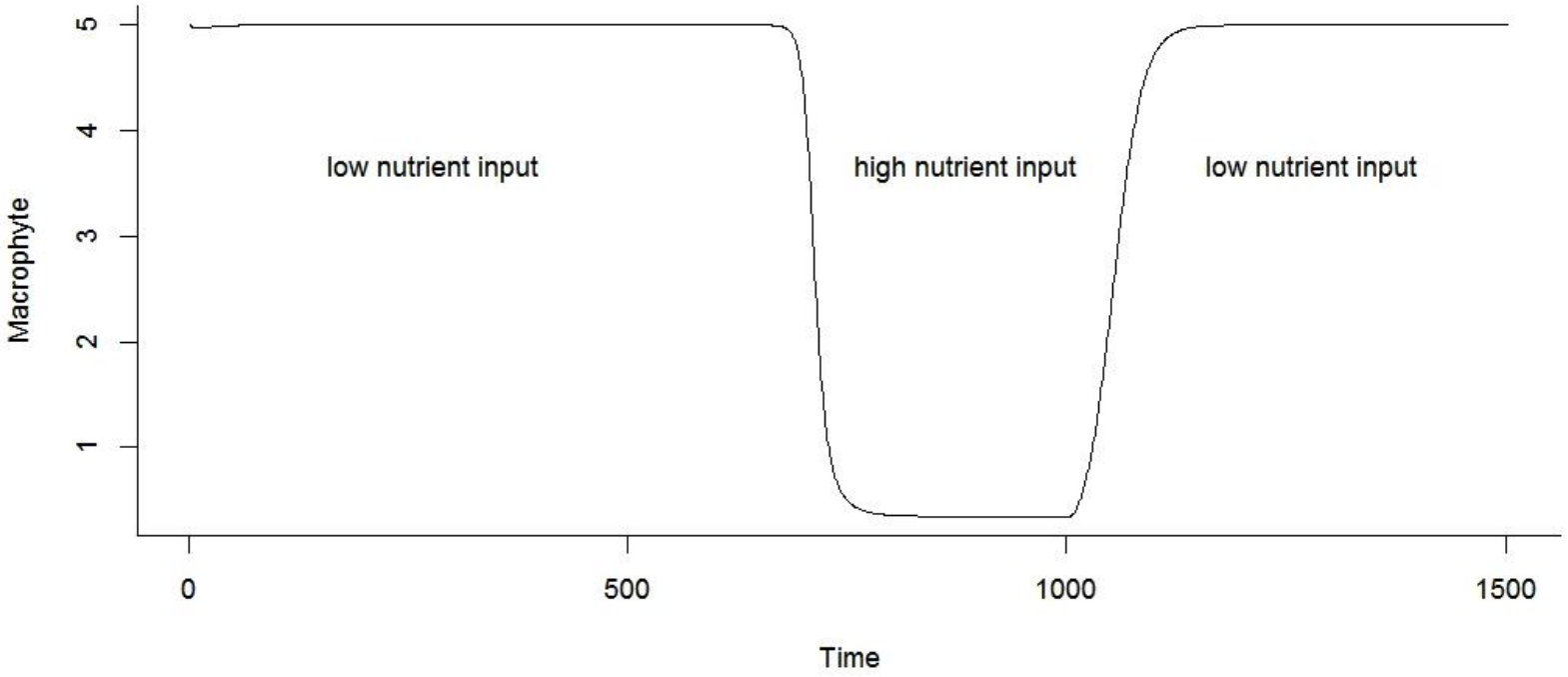
$M_0 >> F_0$



$F_0 >> M_0$



The behaviour of the system with perturbations



Glory and Misery

Glory and Misery

Glory...

ICTP SAIFR

Glory and Misery

Glory...

- We found hysteresis!!!

Glory and Misery

Glory...

- We found hysteresis!!!
- The model shows the expected behaviour for N, M and F;

Glory and Misery

Glory...

- We found hysteresis!!!
- The model shows the expected behaviour for N, M and F;
- The dynamics of the system makes biological sense;

Glory and Misery

Glory...

- We found hysteresis!!!
- The model shows the expected behaviour for N, M and F;
- The dynamics of the system makes biological sense;
- Few parameters can explan a complex behaviour.

Glory and Misery

Glory...

- We found hysteresis!!!
- The model shows the expected behaviour for N, M and F;
- The dynamics of the system makes biological sense;
- Few parameters can explan a complex behaviour.

Misery...

Glory and Misery

Glory...

- We found hysteresis!!!
- The model shows the expected behaviour for N, M and F;
- The dynamics of the system makes biological sense;
- Few parameters can explan a complex behaviour.

Misery...

- The model is VERY simple;

ICTP SAIFR

Glory and Misery

Glory...

- We found hysteresis!!!
- The model shows the expected behaviour for N, M and F;
- The dynamics of the system makes biological sense;
- Few parameters can explain a complex behaviour.

Misery...

- The model is VERY simple;
- There isn´t a carrying capacity for biomass of Phytoplankton.

ICTP SAIFR

Bibliography

Blindow, I. *et al.*, Long-term pattern of alternative stable states in two shallow eutrophic lakes. *Freshwater Biology* 30 (1993), 159.

Scheffer, M. *et al.*, Catastrophic shifts in ecosystems, *Nature* 413 (2001) 591. **http://www.nature.com/nature/journal/v413/n6856/full/413591a0.html**

Oguz, T. and Velikova, V. , Abrupt transition of the northwestern Black Sea shelf ecosystem from a eutrophic to an alternative pristine state. *Marine Ecology Progress Series* 405 (2010) 231. **http://www.int-res.com/articles/meps2010/405/m405p231.pdf**

Karrlson, J. *et al.*, Light limitation of nutrient-poor lake ecosystems. *Nature* 460 (2009)506. **http://www.nature.com/nature/journal/v460/n7254/full/nature08179.html**

Scheffer, M. and Egbert H. Shallow lakes theory revisited: various alternative regimes driven by climate, nutrients, depth and lake size. *Hydrobiologia* (2007) 584:455–466.

ICTP SAIFR

Bibliography

Petraitis, P. and Catharine H, Multiple stable states and relationship between thresholds in processes and states, *Marine Ecology Progress Series* (2010) 413: 189–200.

May, R. Thresholds and breakpoints in ecosystems with a multiplicity of stable states. *Nature* 269, 471 - 477 (06 October 1977).

Scheffer, M. *et al.*, Alternative equilibria in shallow lakes. *Trends in Ecology & Evolution*, Volume 8, Issue 8, 275-279, 1 August 1993.

Scheffer, M. and Steven C. Catastrophic regime shifts in ecosystems: linking theory to observation, Review. *Trends in Ecology and Evolution* Vol.18 No.12 December 2003.

Genkai-Kato, M. Regime shifts: catastrophic responses of ecosystems to human impacts. *Ecological Rasearch*, 269, 471 - 477 (6 October 1977).

Scheffer, M. *et al.*, Alternative equilibria in shallow lakes. *Trends in Ecology & Evolution*, Volume 8, Issue 8, 275-279, 1 August 1993.

ICTP SAIFR

Acknowledgements

Thanks...

Acknowledgements

Thanks...

for all the t.a.`s and the teachers for the support;

Acknowledgements

Thanks...

for all the t.a.`s and the teachers for the support;

IFT – UNESP;

Acknowledgements

Thanks...

for all the t.a.`s and the teachers for the support;

IFT – UNESP;

Roberto Kraenkel;

Acknowledgements

Thanks...

for all the t.a.`s and the teachers for the support;

IFT – UNESP;

Roberto Kraenkel;

and all the colleagues!!