LIMNOLOGÍA 2022

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CURE Centro Universitario Regional del Este
UNIVERSIDAD DE LA REPÚBLICA URUGUAY

REGIME SHIFTS: BASIC CONCEPTS AND EXAMPLES FROM PANTANAL FLOODPLAIN

UNIVERSIDAD DE LA REPUBLICA
URUGUAY

LIMNOLOGIA 2022

SARAS²
South American Institute for Resilience and Sustainability Studies

BASIC CONCEPTS
EXAMPLES
PERSPECTIVES

BASIC CONCEPTS

Regime shifts can be defined as abrupt changes on several trophic levels promoting rapid ecosystem reconfiguration between alternative states (or regimes).

Review

Cell PRESS

Ecological thresholds and regime shifts: approaches to identification

Tom Andersen[1], Jacob Carstensen[2], Emilio Hernández-García[3] and Carlos M. Duarte[4]

[1] Department of Biology, University of Oslo, PO Box 1066, Blindern, N0316 Oslo, Norway
[2] National Environmental Research Institute, University of Aarhus, PO Box 358, DK-4000 Roskilde, Denmark
[3] Instituto de Física Interdisciplinar y Sistemas Complejos, IFISC (CSIC-UIB), Campus Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain
[4] Instituto Mediterráneo de Estudios Avanzados, IMEDEA (CSIC-UIB), C/Miquel Marqués 21, 07190 Esporles (Islas Baleares), Spain

Trends in Ecology and Evolution Vol.24 No.1

These shifts are driven by external perturbations (e.g. climatic fluctuation, overexploitation, eutrophication and invasive species) and/or by the system´s internal dynamics, but the exact mechanism is often unclear.

Review

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Ecological thresholds and regime shifts: approaches to identification

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Trends in Ecology and Evolution Vol.24 No.1

Abrupt ecosystem changes often result from nonlinear dynamics, however, such changes can also result from linear state changes in response to sudden changes in external pressure.

Review

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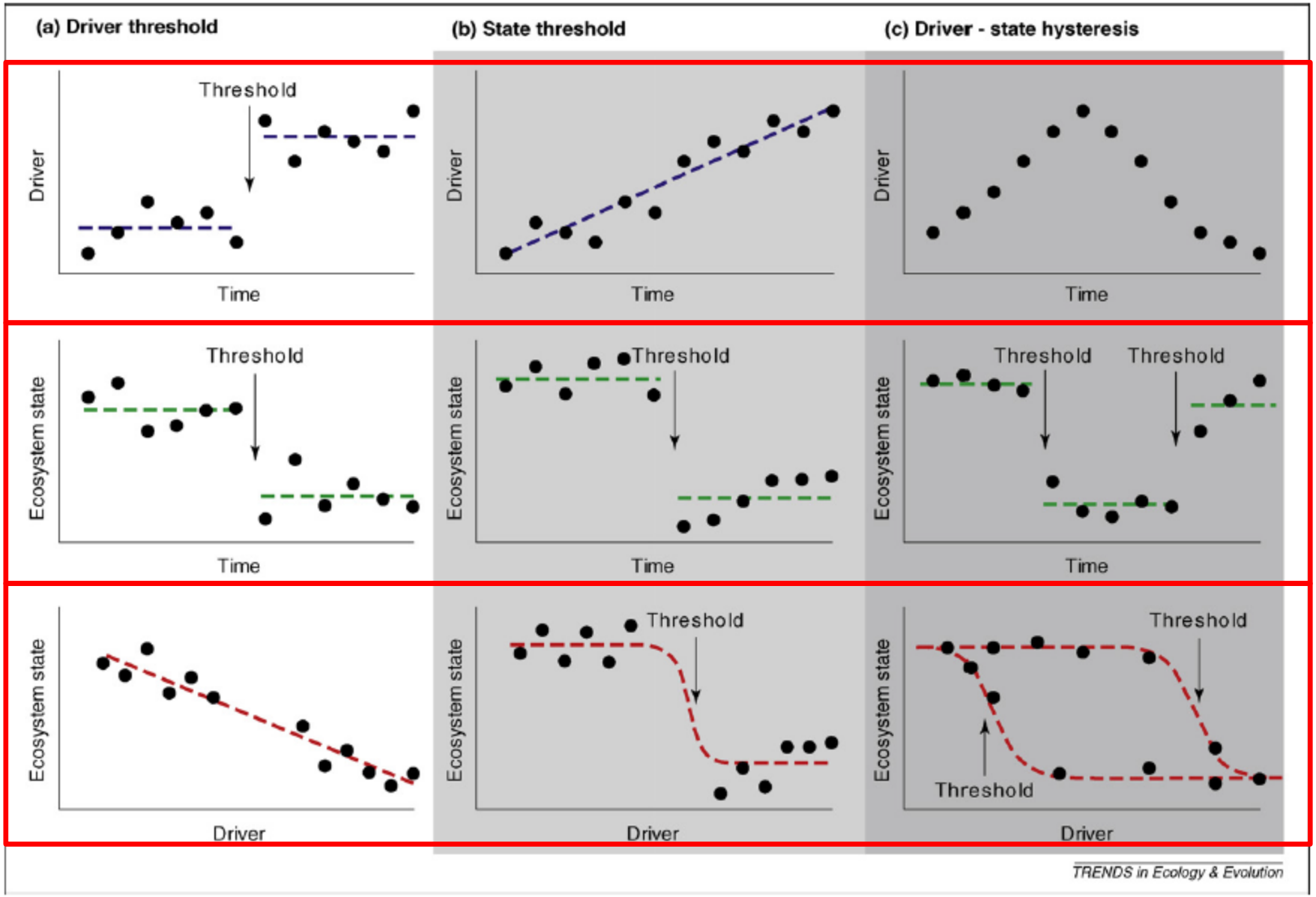
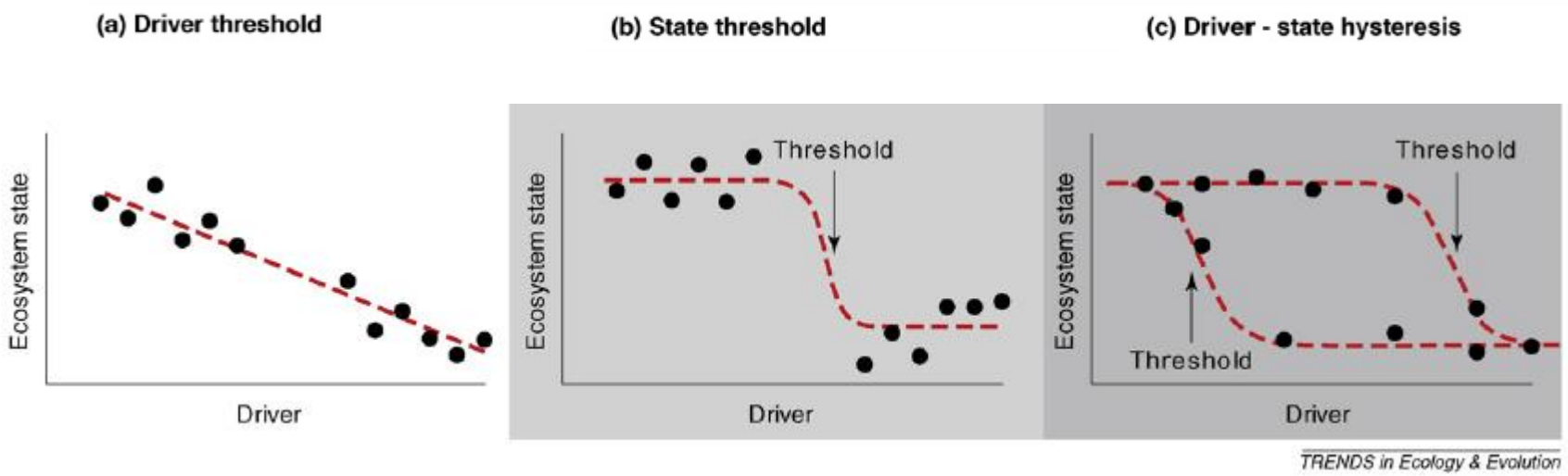
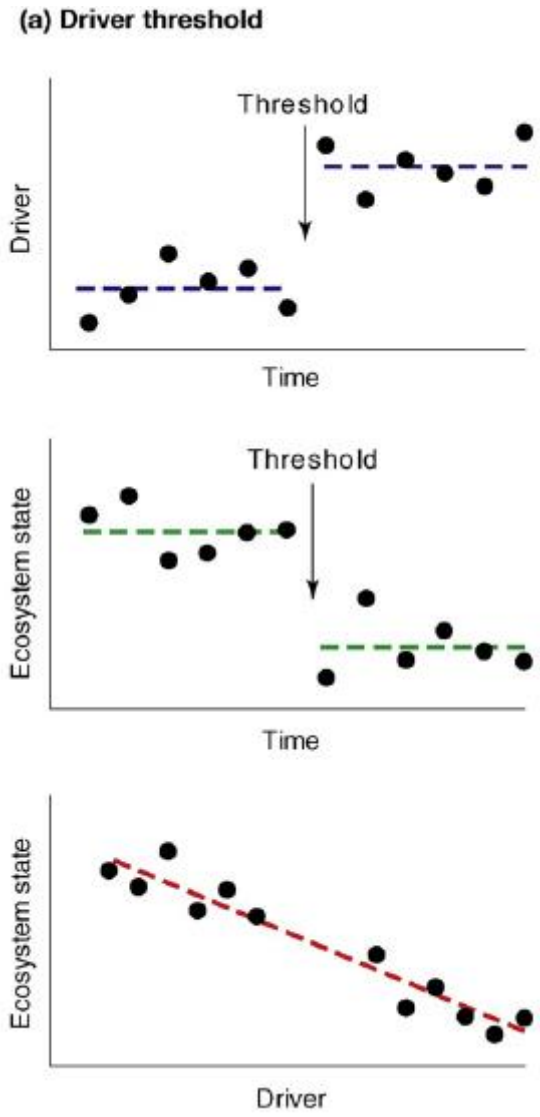
Trends in Ecology and Evolution Vol.24 No.1

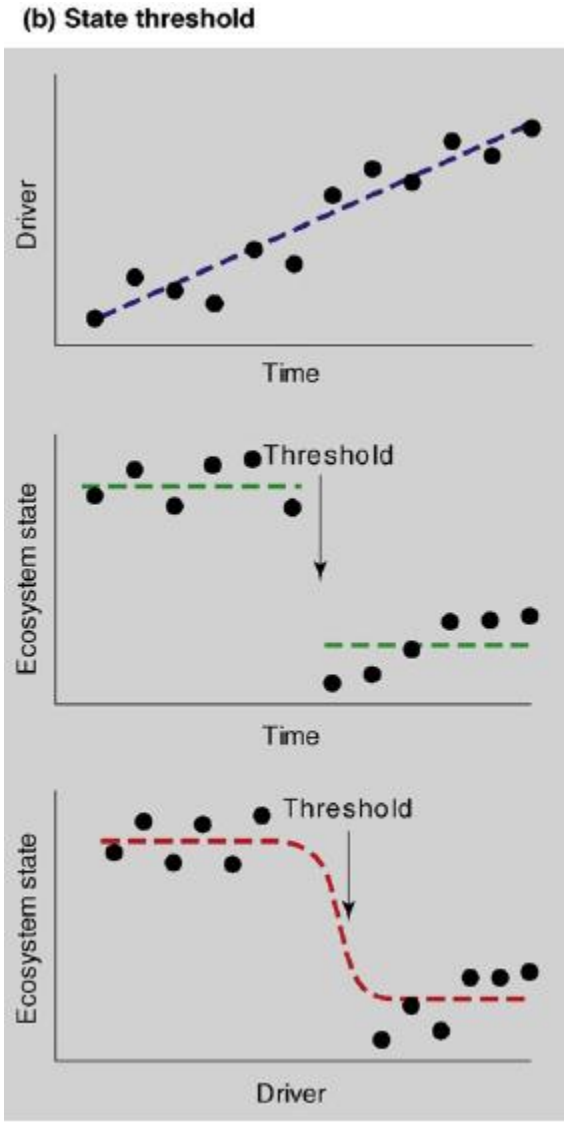

(a) Driver threshold
(b) State threshold
(c) Driver - state hysteresis
Threshold
Driver
Time
Ecosystem state
Threshold
Time
Threshold
Threshold
Time
Ecosystem state
Driver
Threshold
Driver
Threshold
Threshold
Driver
TRENDS in Ecology & Evolution



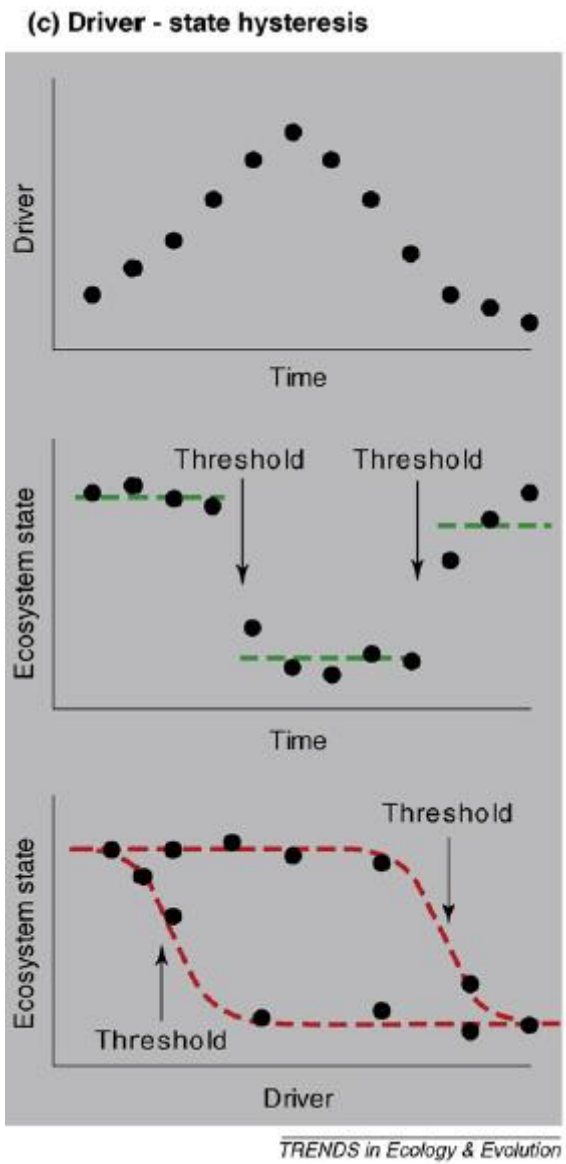
There are three main ways by which an ecological system might exhibit changes over time, two are reversible in response to drivers, a third possibility and most undesirable one is not.



Regime shift in driver linearly mediated to the ecosystem state.



Regime shift in ecosystem state after driver exceeds a threshold.



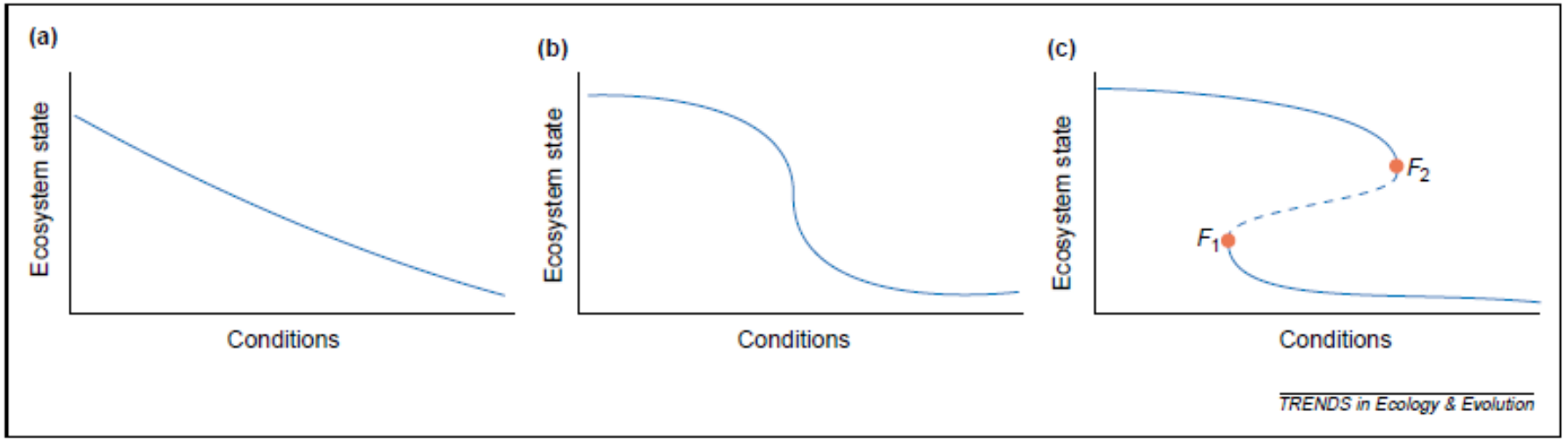
The hysteresis loop linking the ecosystem state to the environmental driver results in jumps between two alternative states when the driver is first slowly increased and the decreased again.

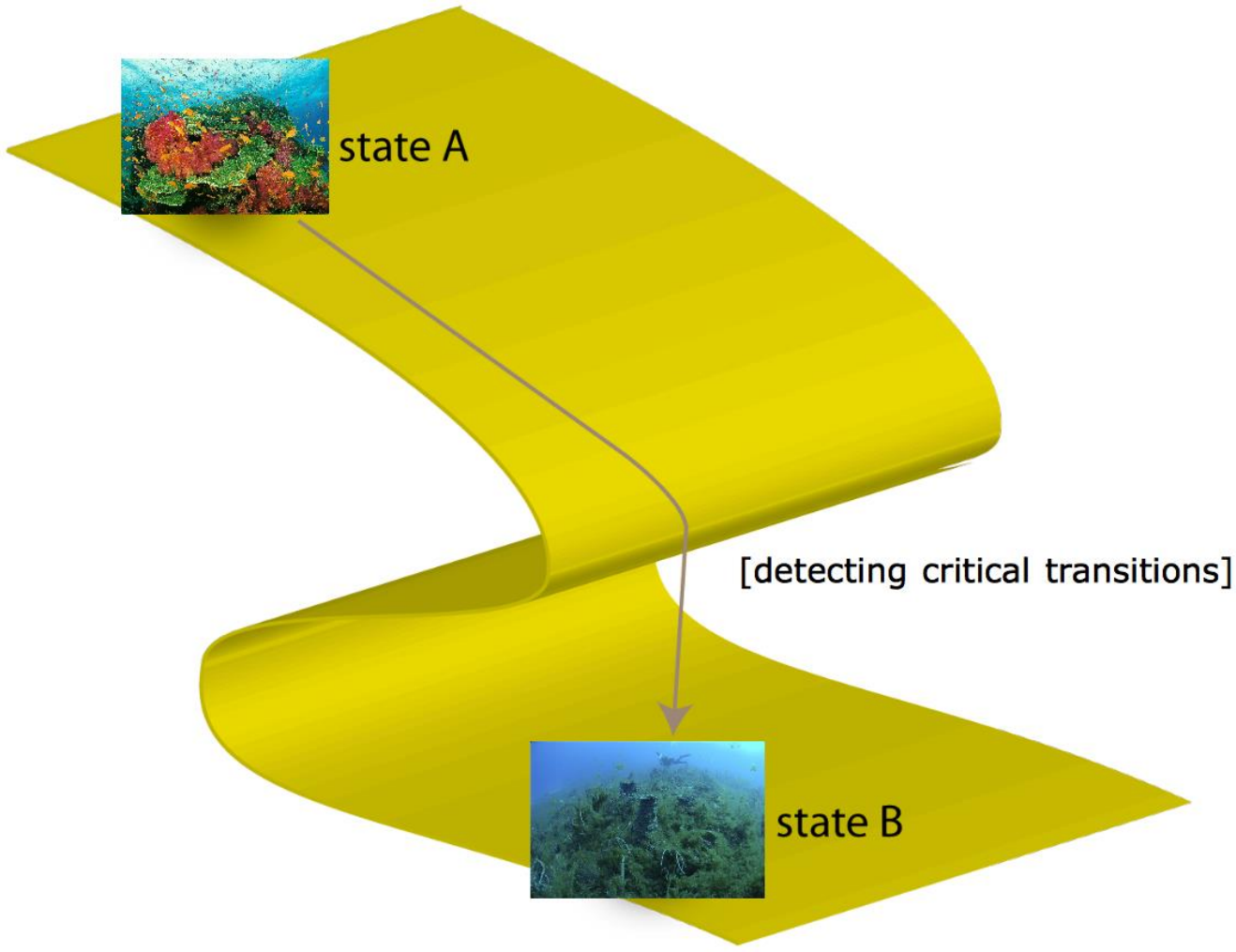
ELSEVIER

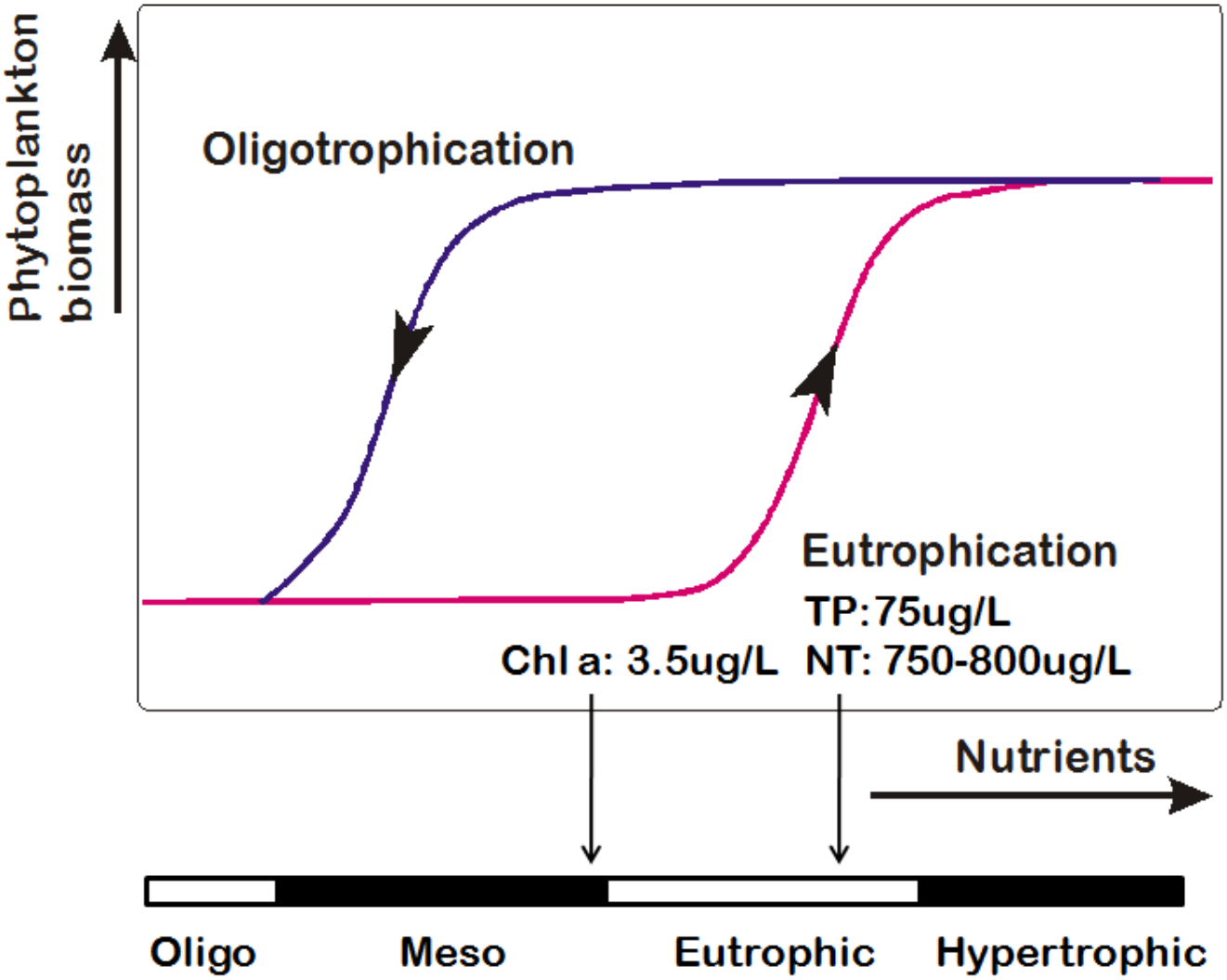
Catastrophic regime shifts in ecosystems: linking theory to observation

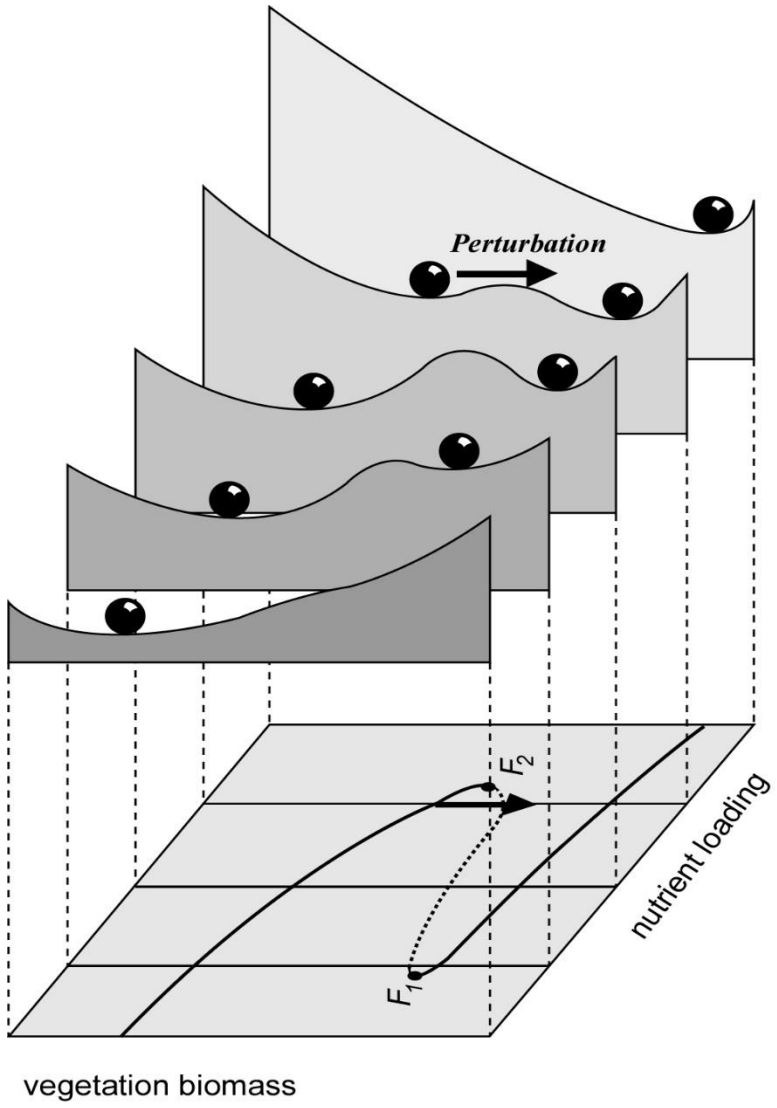
Marten Scheffer[1] and Stephen R. Carpenter[2]

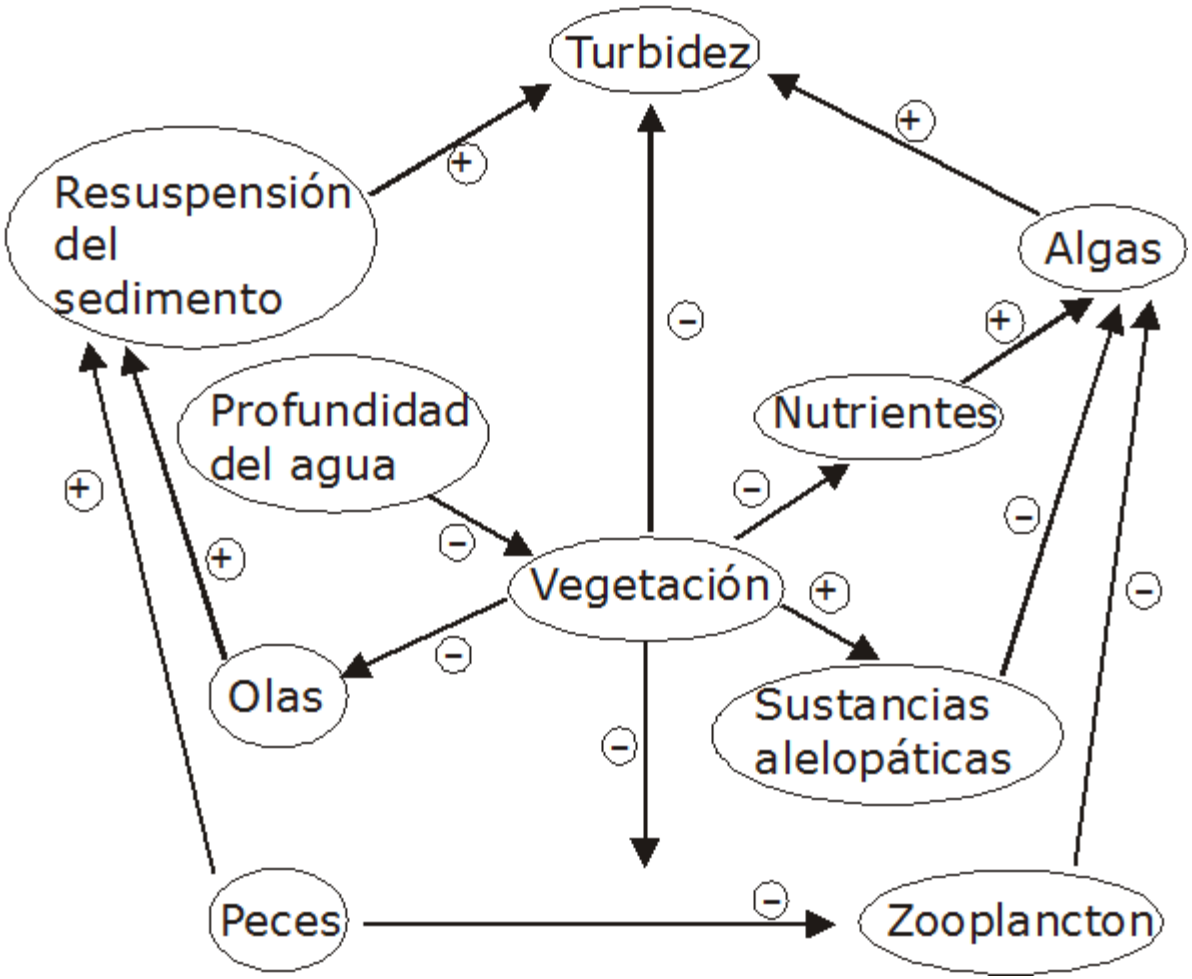
[1]Department of Aquatic Ecology and Water Quality Management, Wageningen University, PO Box 8080, 6700 DD Wageningen, The Netherlands
[2]Center for Limnology, University of Wisconsin, 680 North Park Street, Madison, WI 53706, USA


(a)
Ecosystem state
Conditions
(b)
Ecosystem state
Conditions
(c)
Ecosystem state
F_2
F_1
Conditions
TRENDS in Ecology & Evolution


state A
[detecting critical transitions]
state B


Phytoplankton biomass
Oligotrophication
Eutrophication
TP:75ug/L
Chl a: 3.5ug/L
NT: 750-800ug/L
Nutrients
Oligo
Meso
Eutrophic
Hypertrophic


Perturbation
F2
F1
nutrient loading
vegetation biomass

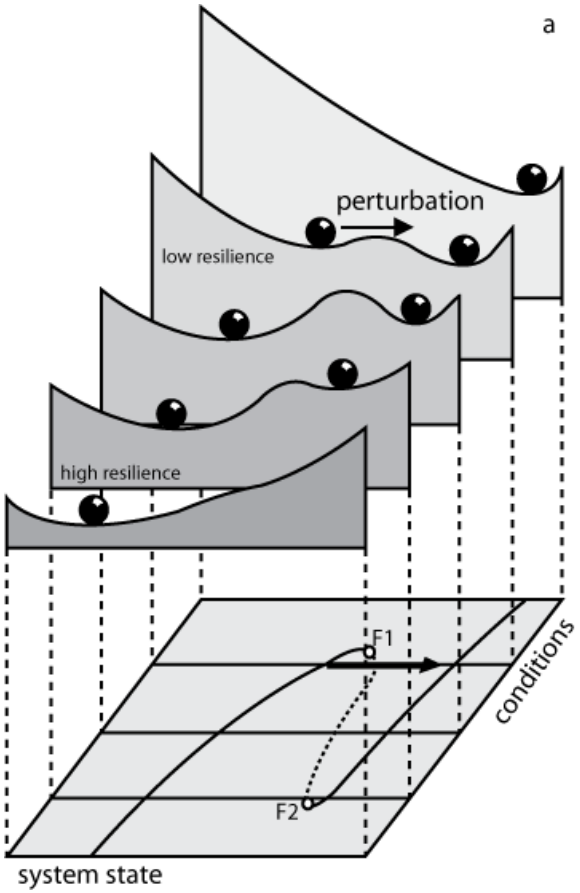

Turbidez
Resuspensión del sedimento
Algas
Profundidad del agua
Nutrientes
Vegetación
Olas
Sustancias alelopáticas
Peces
Zooplancton
+
+
+
+
+
+
+
−
−
−
−
−
−
−
−

Vol 461|3 September 2009|doi:10.1038/nature08227 nature

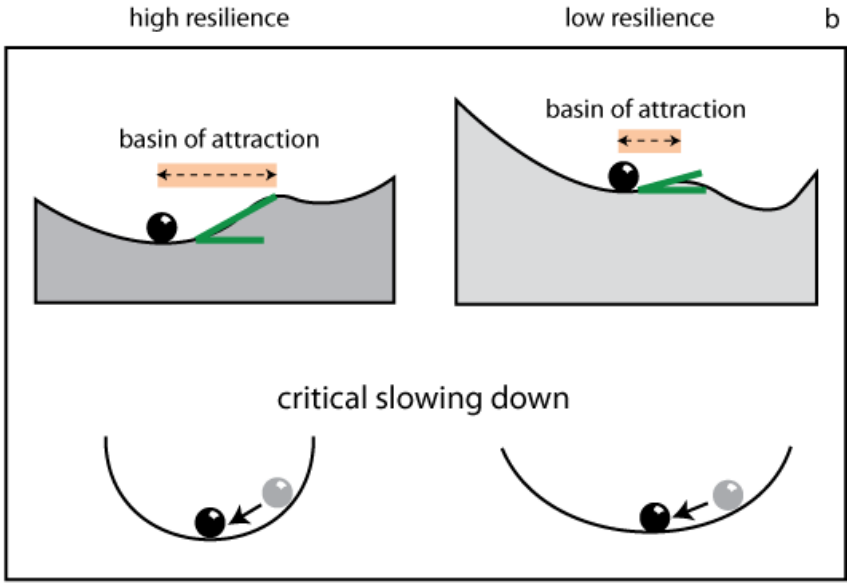
REVIEWS

Early-warning signals for critical transitions

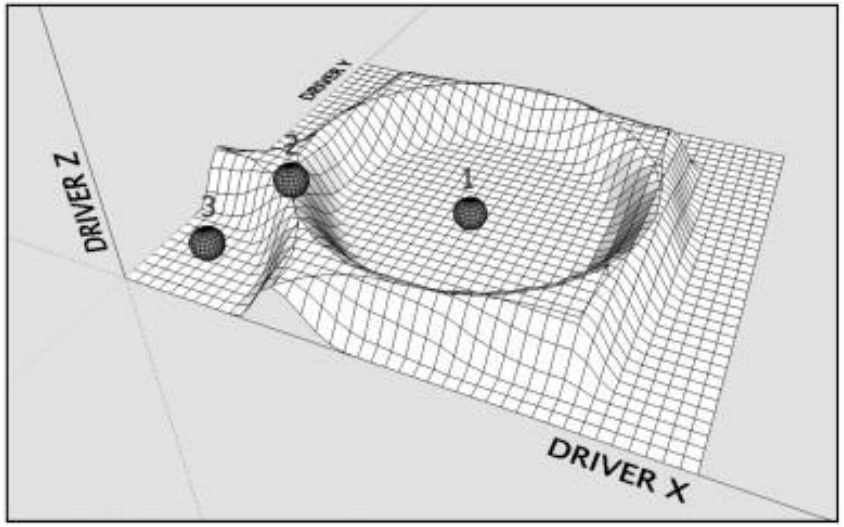
Marten Scheffer[1], Jordi Bascompte[2], William A. Brock[3], Victor Brovkin[5], Stephen R. Carpenter[4], Vasilis Dakos[1], Hermann Held[6], Egbert H. van Nes[1], Max Rietkerk[7] & George Sugihara[8]



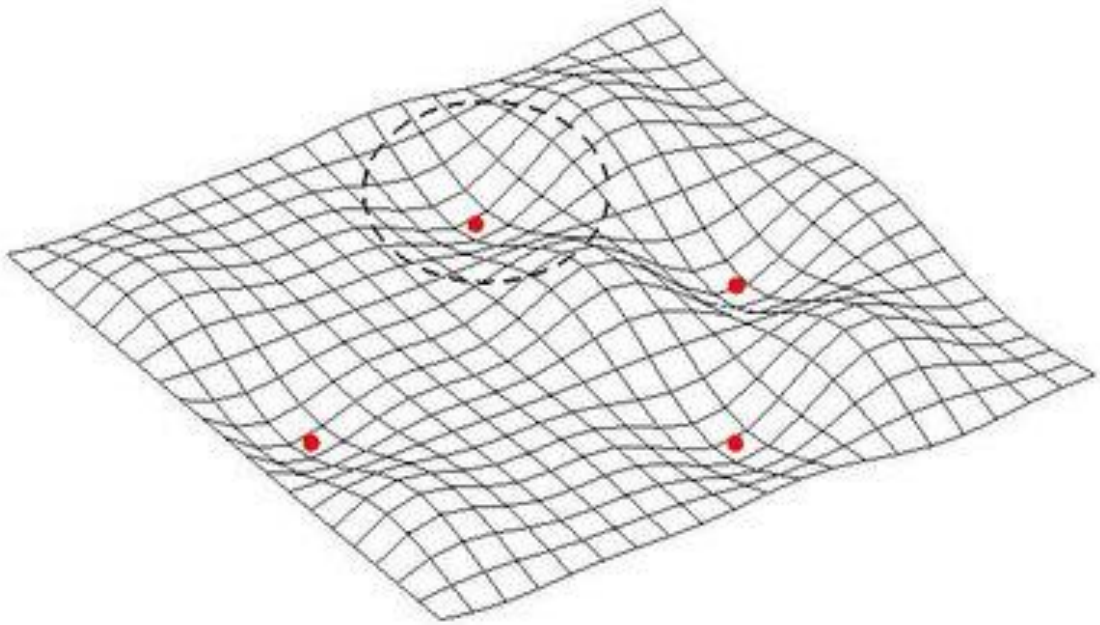
The systems close to the threshold show several attributes denominated critical slowing down.

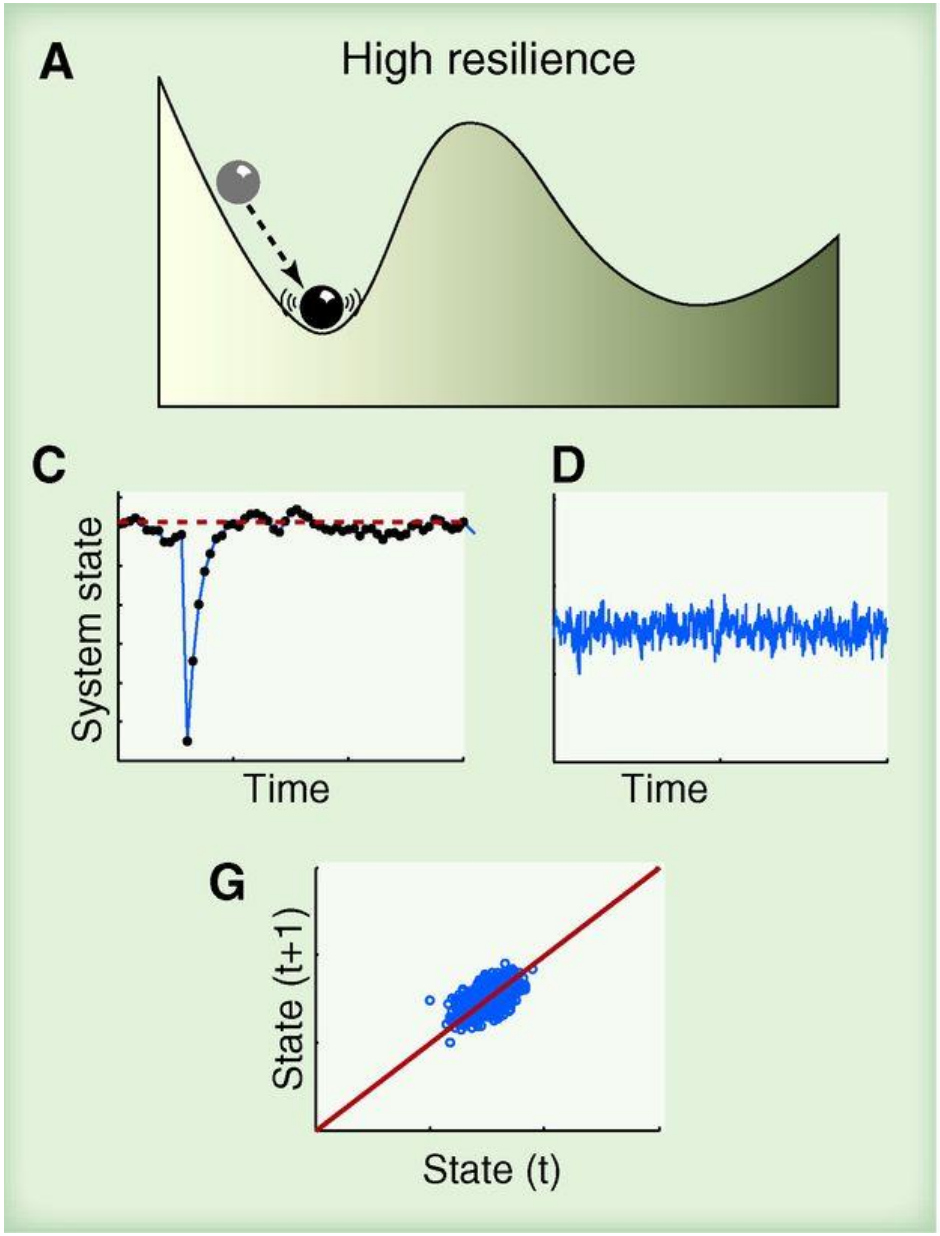


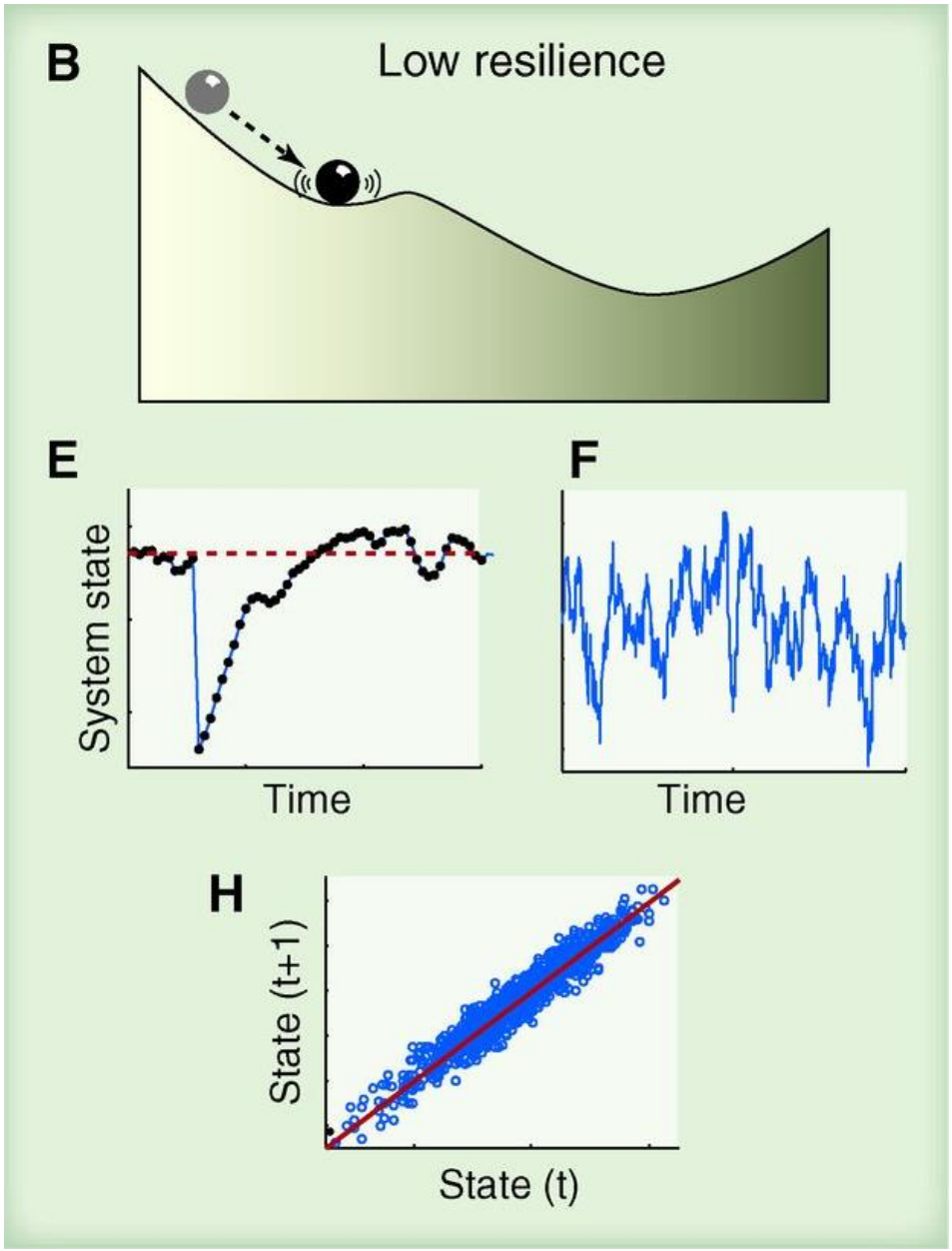
What means **basin attraction?**



What means **basin attraction?**




A
High resilience
C
System state
Time
D
Time
G
State (t+1)
State (t)


B
Low resilience
E
System state
Time
F
Time
H
State (t+1)
State (t)

EXAMPLES

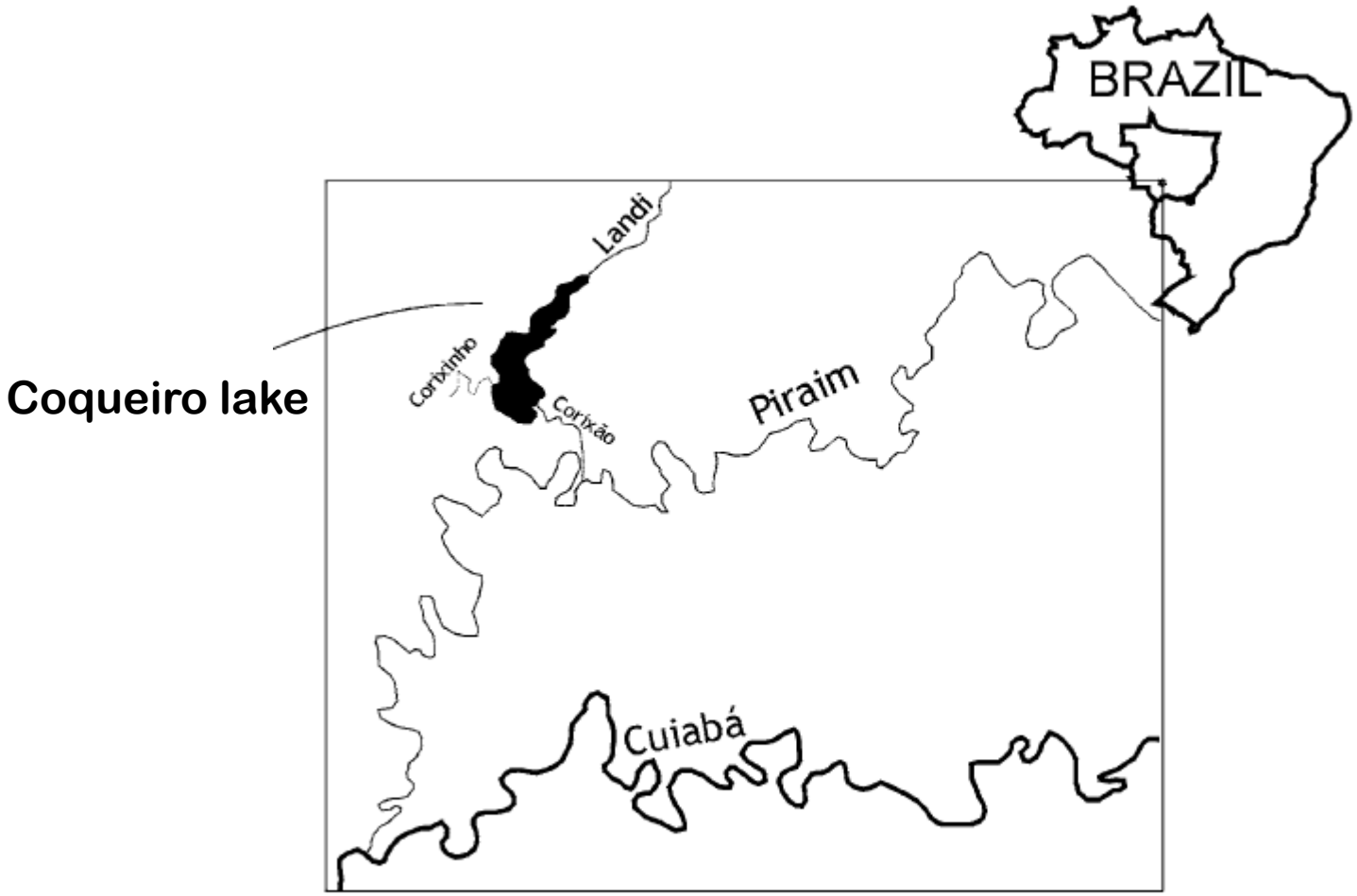
Ecosystems (2009) 12: 807–819
DOI: 10.1007/s10021-009-9258-0

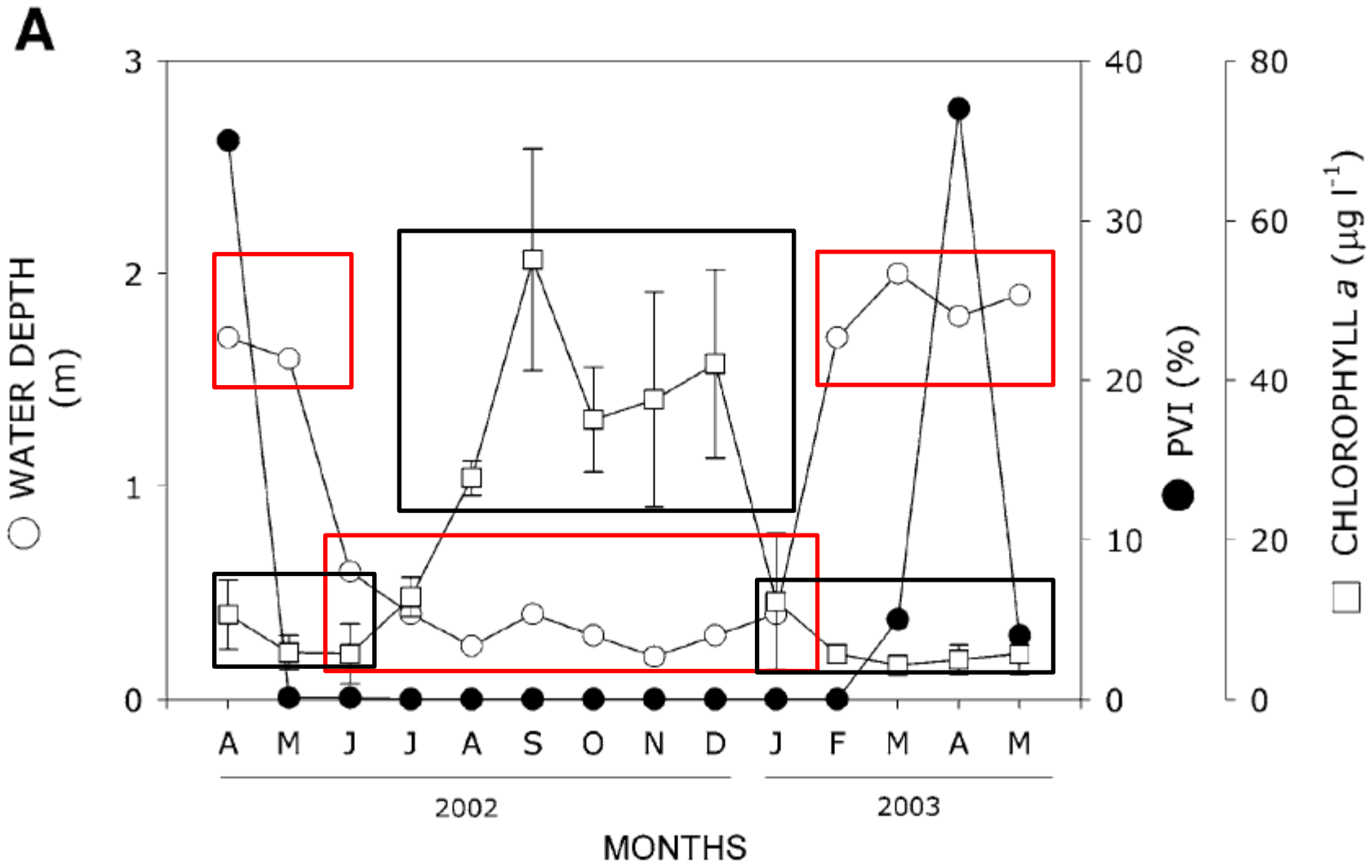
ECOSYSTEMS

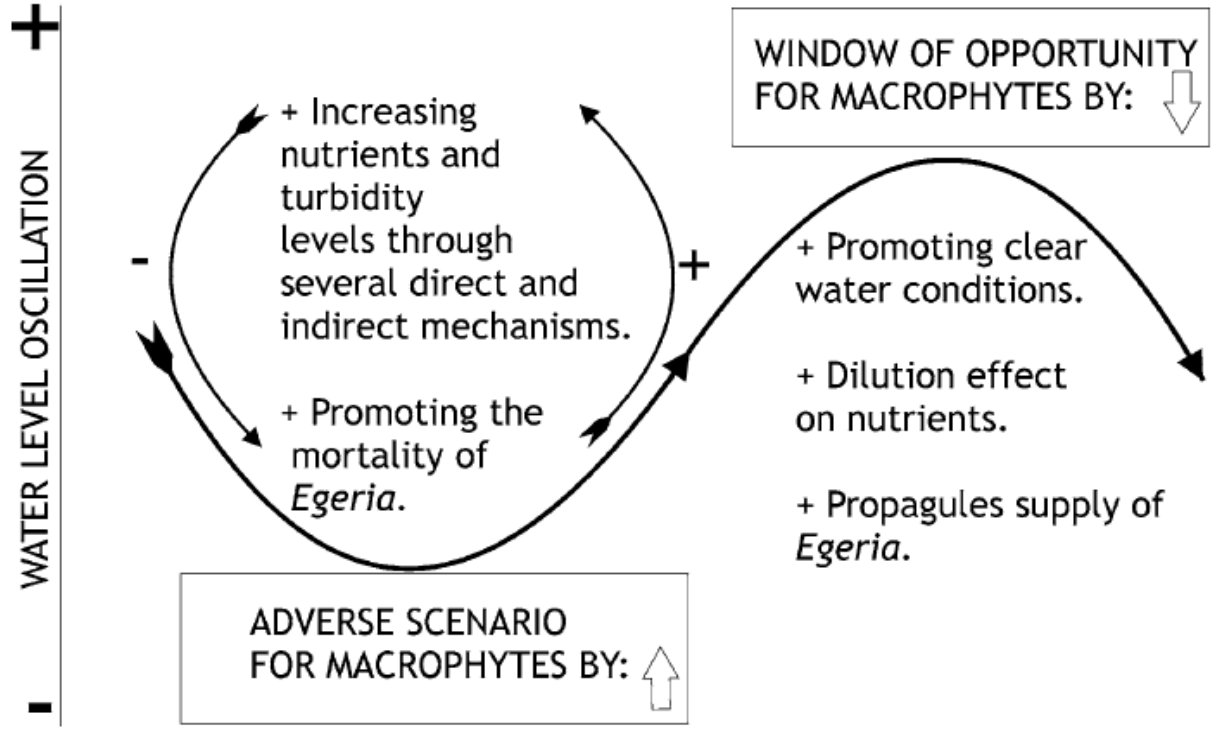
Hydrology-Driven Regime Shifts in a Shallow Tropical Lake

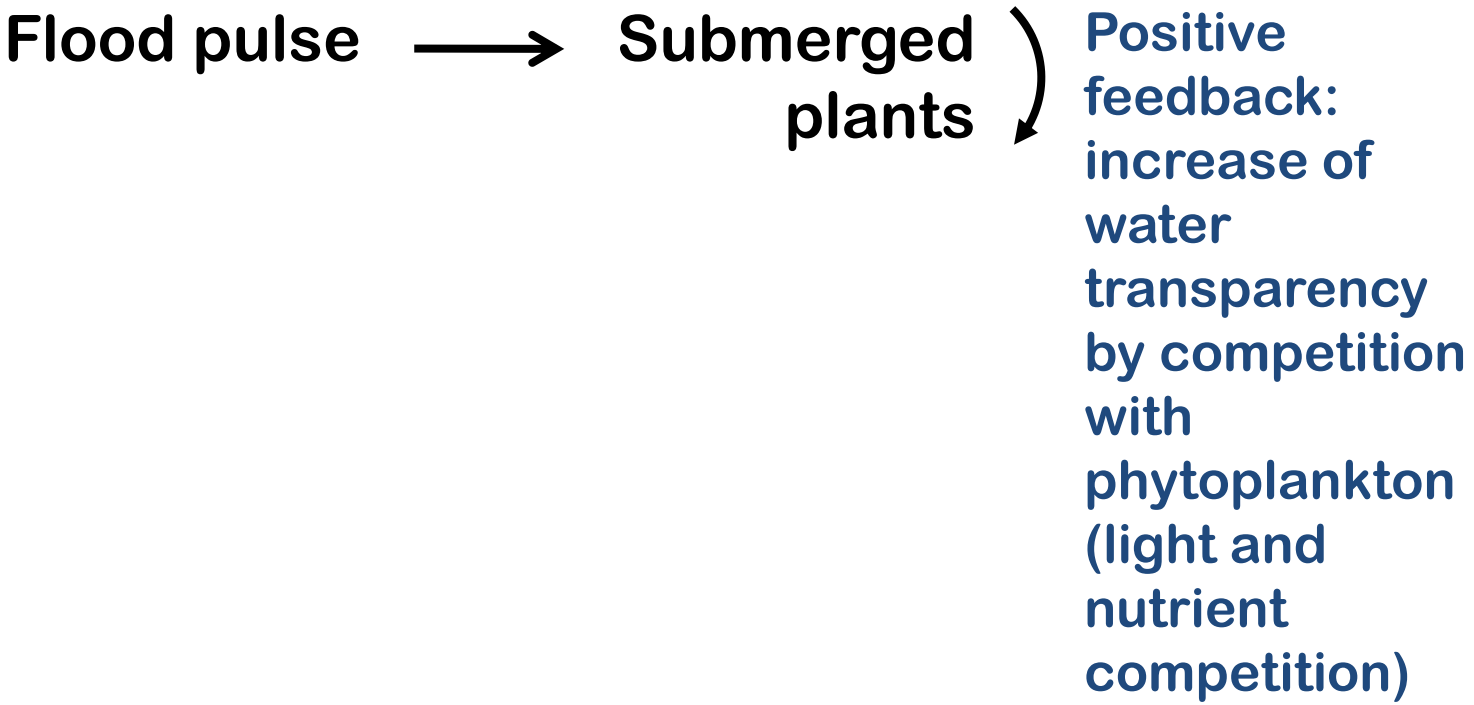
Simoni Maria Loverde-Oliveira,[1]* Vera Lúcia Moraes Huszar,[2] Nestor Mazzeo,[3] and Marten Scheffer[4]

[1]Depto. Ciências Biológicas, Universidade Federal do Mato Grosso, Rondonópolis, MT 78000-000, Brazil; [2]Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ 20940-040, Brazil; [3]Depto. de Ecología, Laboratorio de Ecología y Rehabilitación de Ecosistemas Acuáticos, Universidad de la República, Montevideo, Uruguay; [4]Department of Aquatic Ecology and Water Quality Management, Agricultural University, Wageningen, The Netherlands


BRAZIL
Landi
Coqueiro lake
Corixinho
Corixão
Piraim
Cuiabá


A
○ WATER DEPTH (m)
● PVI (%)
□ CHLOROPHYLL a (µg l-1)
3
2
1
0
40
30
20
10
0
80
60
40
20
0
A M J J A S O N D J F M A M
2002
2003
MONTHS


+
WATER LEVEL OSCILLATION
-
WINDOW OF OPPORTUNITY FOR MACROPHYTES BY:
+ Increasing nutrients and turbidity levels through several direct and indirect mechanisms.
+ Promoting the mortality of *Egeria*.
+ Promoting clear water conditions.
+ Dilution effect on nutrients.
+ Propagules supply of *Egeria*.
ADVERSE SCENARIO FOR MACROPHYTES BY:


Flood pulse
Submerged plants
Positive feedback: increase of water transparency by competition with phytoplankton (light and nutrient competition)

Resilience indicators: prospects and limitations for early warnings of regime shifts

Vasilis Dakos[1], Stephen R. Carpenter[2], Egbert H. van Nes[3] and Marten Scheffer[3]

[1]Integrative Ecology Group, Estación Biológica de Doñana, c/Américo Vespucio s/n, Seville 41092, Spain
[2]Center for Limnology, University of Wisconsin, Madison, WI 53706, USA
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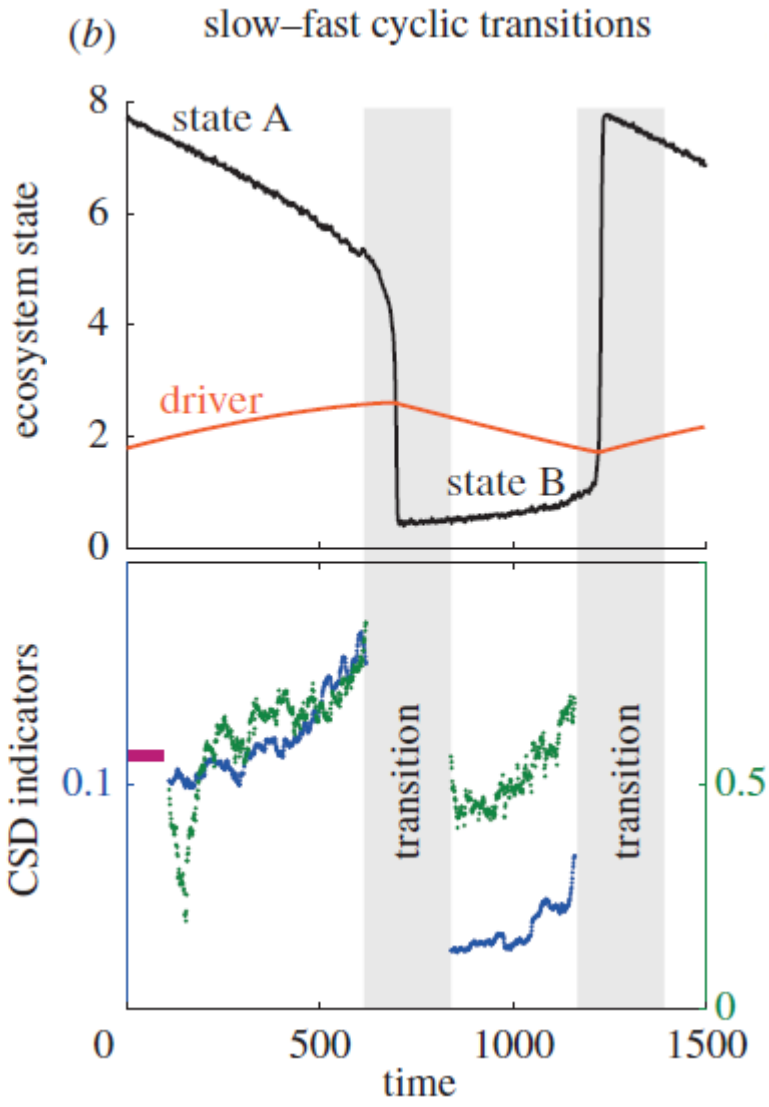
PHILOSOPHICAL TRANSACTIONS B

rstb.royalsocietypublishing.org *Phil. Trans. R. Soc. B* **370**: 20130263



Resilience indicators: prospects and limitations for early warnings of regime shifts

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Some systems have cycles caused by the interaction between fast and slow variables.

Such cycles tend to have relatively abrupt transition, the alternative regime in such cycles are not stable.

Even though there are no formal bifurcation point within such cycles, indicators of CSD may be observed in the dynamics of the fast variables prior the shifts.

Freshwater Biology

Freshwater Biology (2012) **57**, 1592–1602 doi:10.1111/j.1365-2427.2012.02820.x

Migratory benthic fishes may induce regime shifts in a tropical floodplain pond

ROGER P. MORMUL*, SIDINEI M. THOMAZ†, ANGELO A. AGOSTINHO†, CLAUDIA C. BONECKER† AND NESTOR MAZZEO‡

**Pós-graduação em Ecologia de Ambientes Aquáticos Continentais – PEA, Universidade Estadual de Maringá – UEM, Maringá – PR, Brazil*

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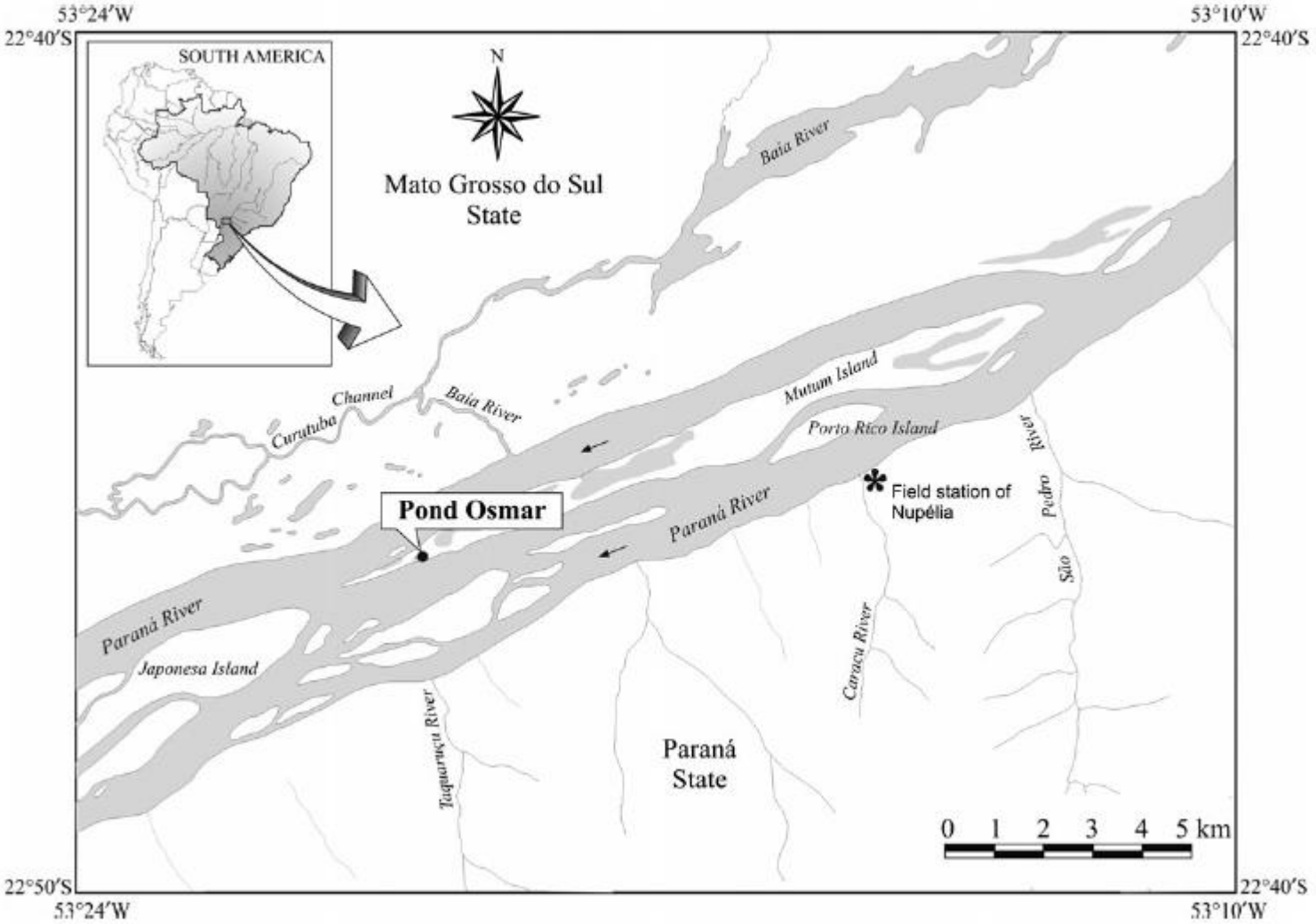
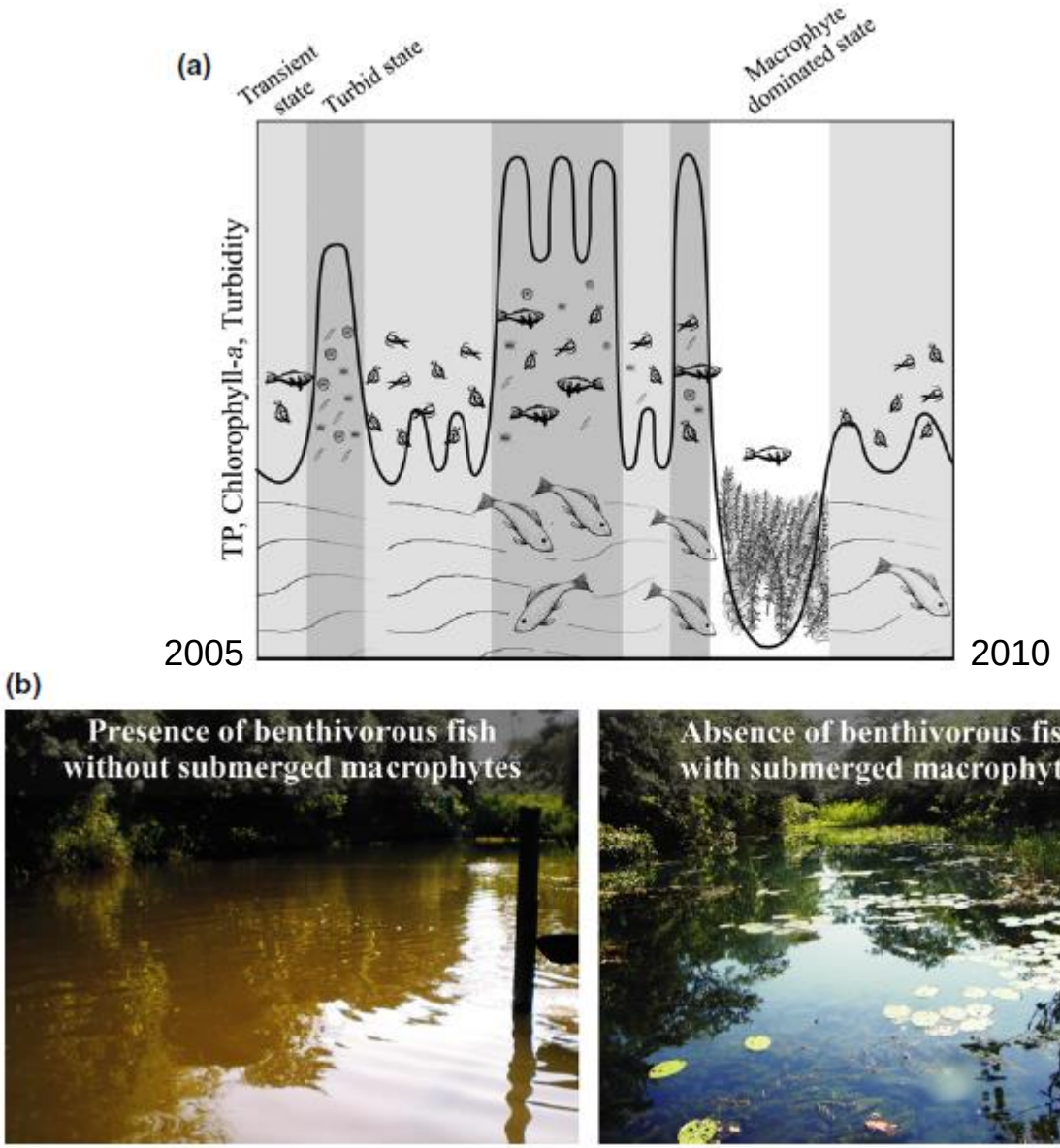
‡Departamento de Ecología & Evolución, CURE-Facultad de Ciencias, Universidad de La Republica, Maldonado, Uruguay


53°24′W
53°10′W
22°40′S
22°40′S
SOUTH AMERICA
N
Mato Grosso do Sul
State
Baía River
Mutum Island
Porto Rico Island
Curutuba
Channel
Baía River
Pond Osmar
Paraná River
Field station of
Nupélia
Pedro
São
Paraná River
Japonesa Island
Caracu River
Taquaruçu River
Paraná
State
0 1 2 3 4 5 km
22°50′S
53°24′W
22°40′S
53°10′W


(a)
Transient state
Turbid state
Macrophyte dominated state
TP, Chlorophyll-a, Turbidity
2005
2010
(b)
Presence of benthivorous fish without submerged macrophytes
Absence of benthivorous fish with submerged macrophytes

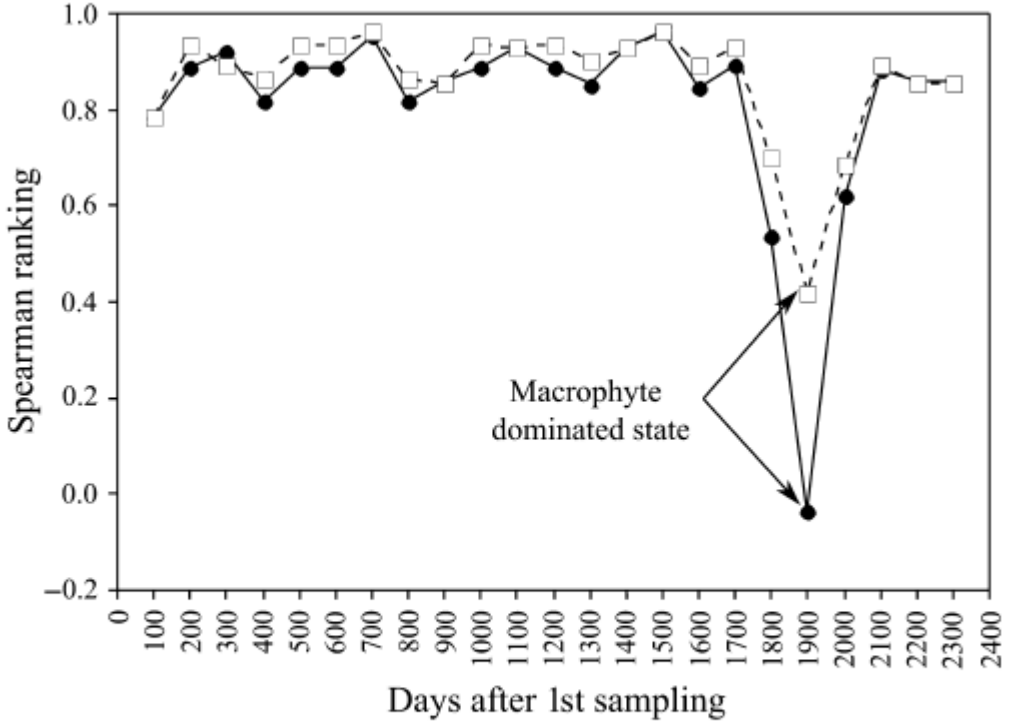


Fig. 3 Values of Spearman's rank correlation of the first sampling date (March 2005) against other sampling dates. The dashed line represents the correlation excluding macrophyte data.

Flood pulse ⟶ Fish community structure ⟶ Turbid or clear regimes

Key role of benthivorous fish on nutrient recirculation and submerged plant colonization

Resilience indicators: prospects and limitations for early warnings of regime shifts

Vasilis Dakos[1], Stephen R. Carpenter[2], Egbert H. van Nes[3] and Marten Scheffer[3]

[1]Integrative Ecology Group, Estación Biológica de Doñana, c/Américo Vespucio s/n, Seville 41092, Spain
[2]Center for Limnology, University of Wisconsin, Madison, WI 53706, USA
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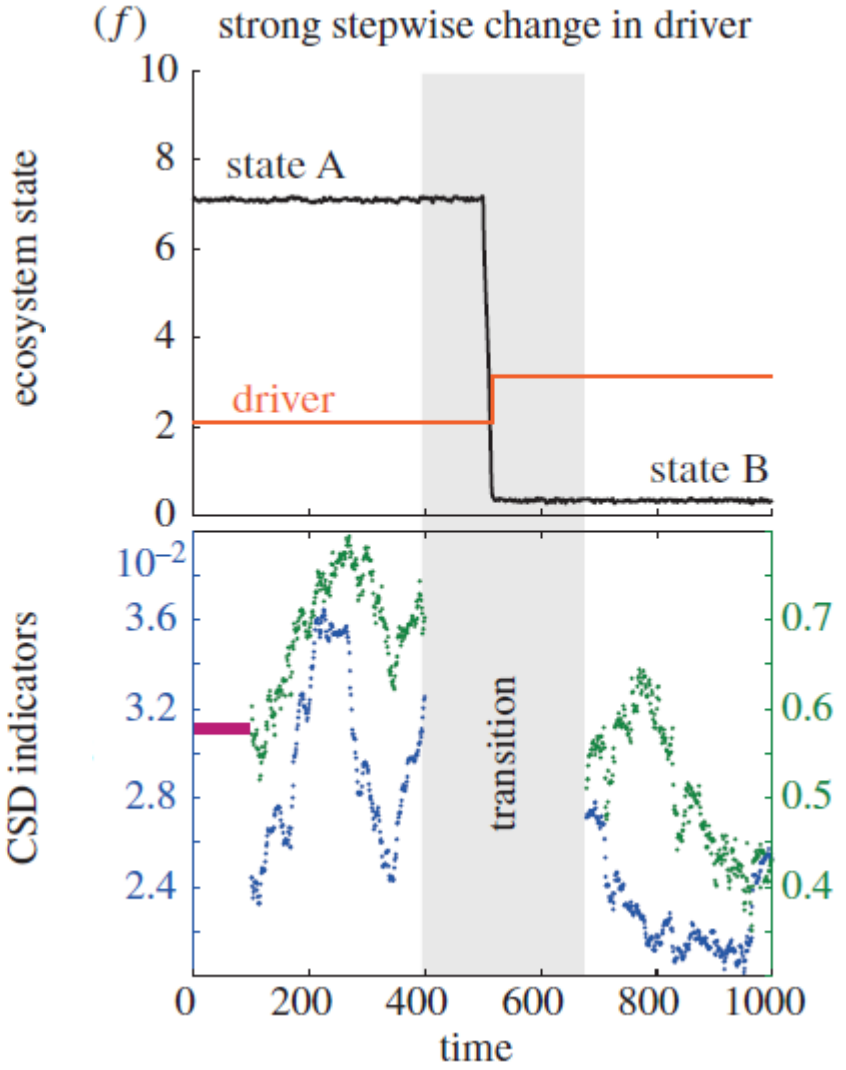

Resilience indicators: prospects and limitations for early warnings of regime shifts

Vasilis Dakos[1], Stephen R. Carpenter[2], Egbert H. van Nes[3] and Marten Scheffer[3]

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[2]Center for Limnology, University of Wisconsin, Madison, WI 53706, USA
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Big stepwise changes sometimes ocurr in environmental conditions.

If these changes are permanent, the ecosystem will move to a new state.

Independently of this state may be an alternative attractor or not, there is no reason to expect any signs of CSD prior to the regime shift.

Science of the Total Environment 605–606 (2017) 527–540

Contents lists available at ScienceDirect

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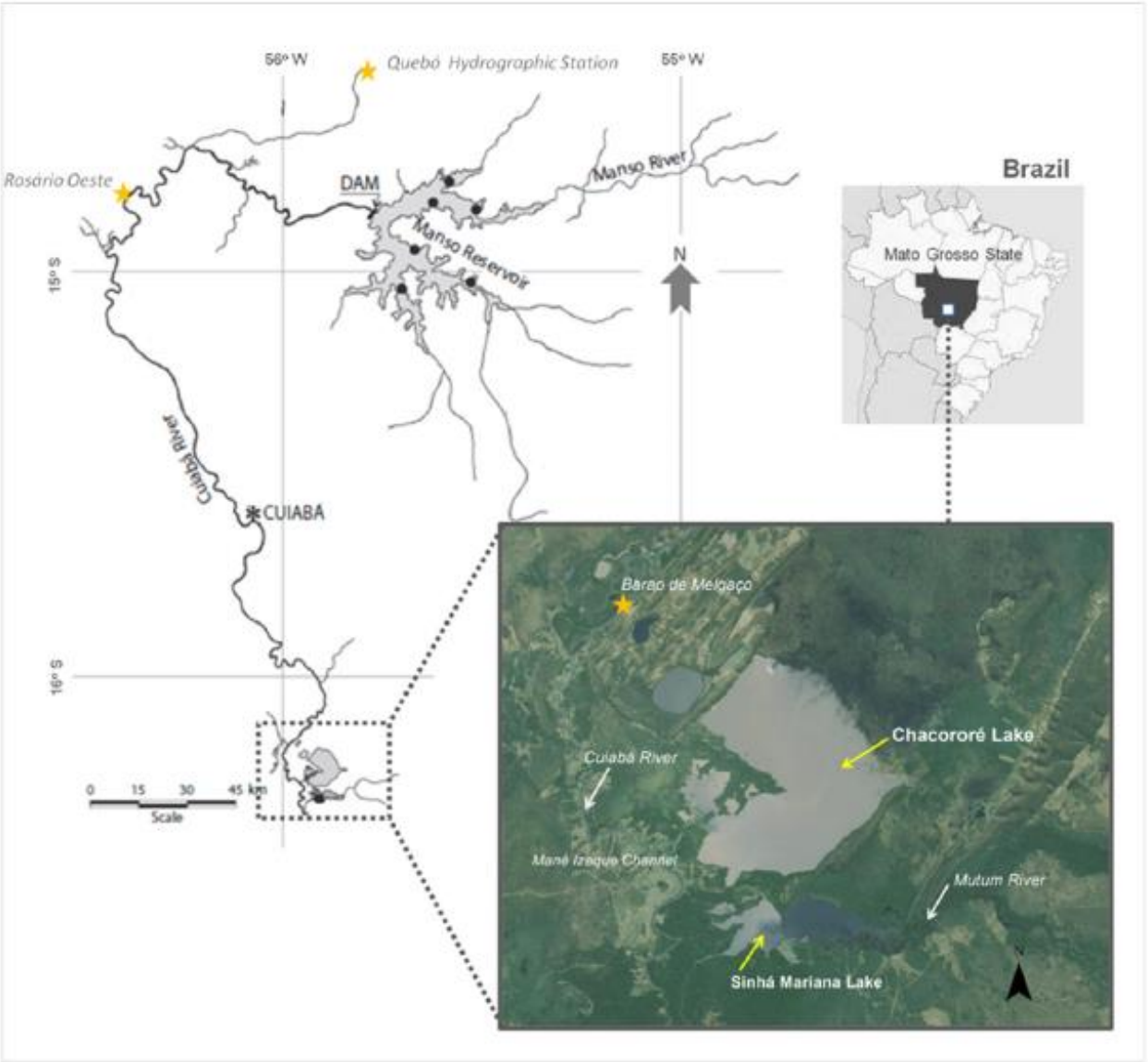
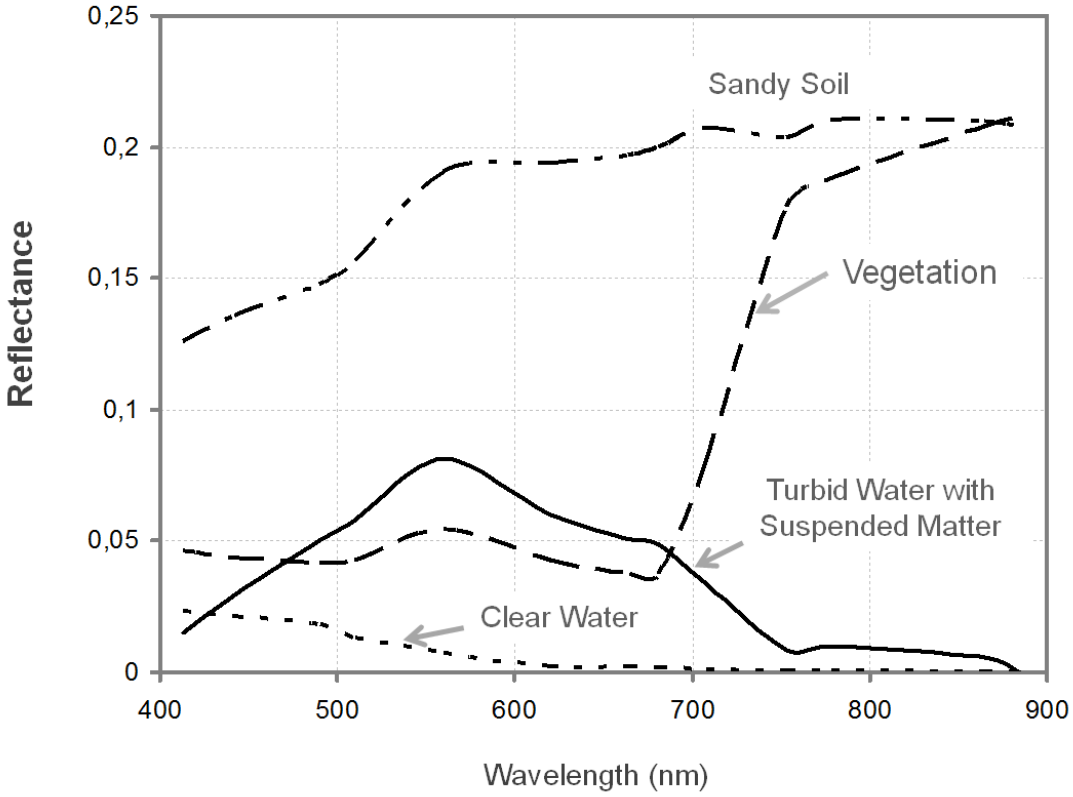
journal homepage: www.elsevier.com/locate/scitotenv

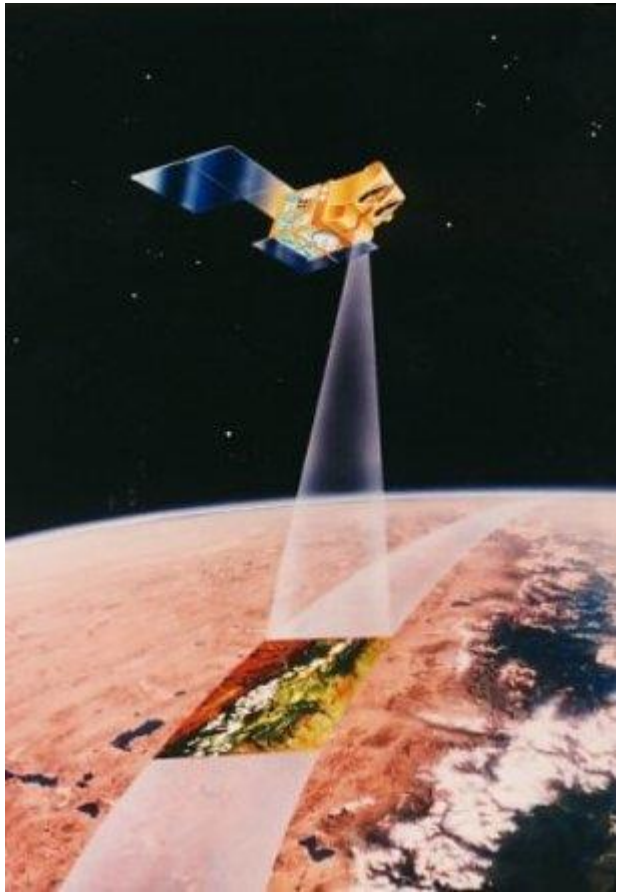
Long-term dynamics of a floodplain shallow lake in the Pantanal wetland: Is it all about climate?

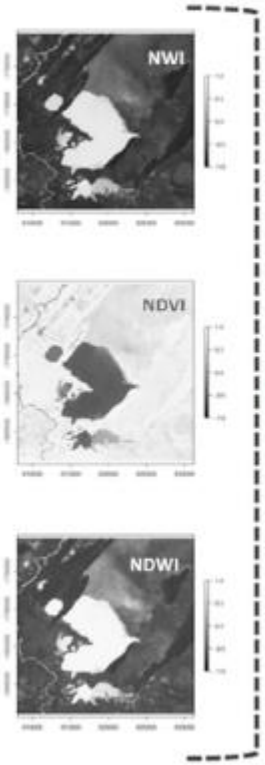
Ana Silio-Calzada [a,*], José Barquín [a], Vera L.M. Huszar [b], Nestor Mazzeo [c], Fernando Méndez [d], Jose Manuel Álvarez-Martínez [a]

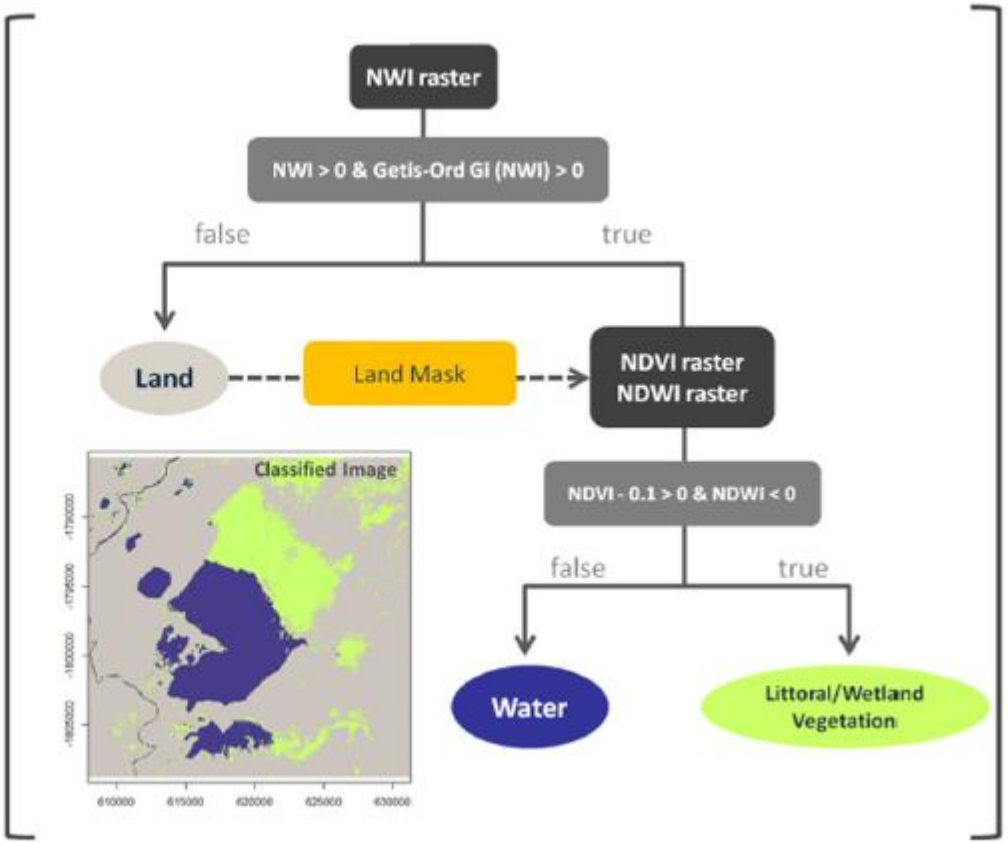
[a] Environmental Hydraulics Institute "IH Cantabria of Universidad de Cantabria", C/ Isabel Torres n°15, Parque Científico y Tecnológico de Cantabria, 39011 Santander, Spain
[b] Museu Nacional, Quinta da Boa Vista, São Cristóvão, 20940-040 Rio de Janeiro, Brazil
[c] CURE-Facultad de Ciencias, Universidad de la República Oriental del Uruguay-UDELAR, Tacuarembó s/n, Maldonado, Uruguay
[d] Universidad de Cantabria, Escuela de Ingenieros de Caminos, Canales y Puertos, Av/ Los Castros, s/n. 39012, Santander, Spain

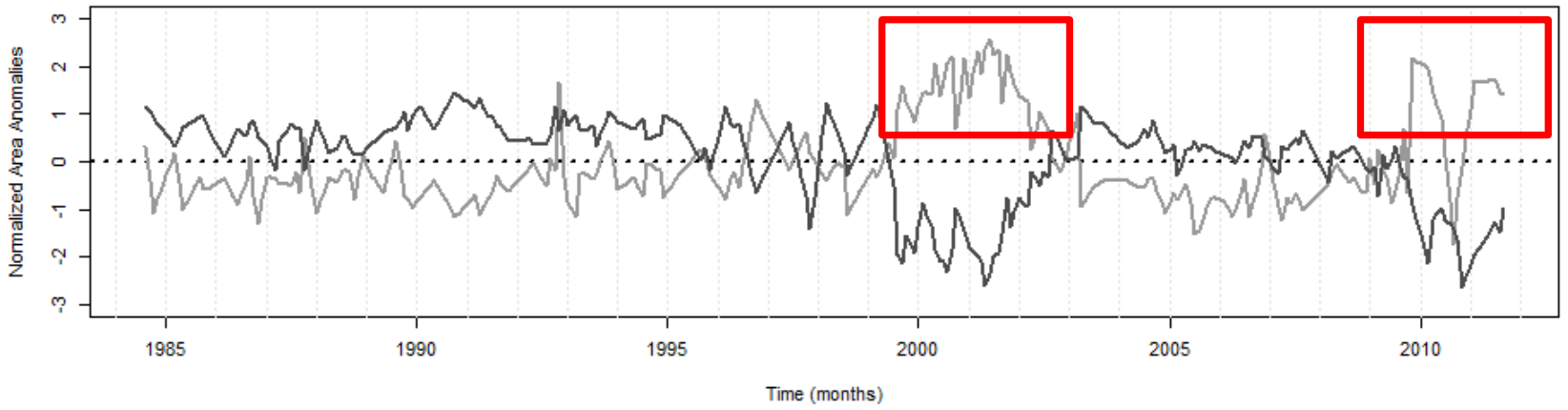

58° W
Quebó Hydrographic Station
55° W
Rosário Oeste
DAM
Manso River
Manso Reservoir
N
Brazil
Mato Grosso State
15° S
Cuiabá River
CUIABA
16° S
0 15 30 45 km
Scale
Barao de Melgaço
Chacororé Lake
Cuiabá River
Mané Izaque Channel
Mutum River
Sinhá Mariana Lake


Reflectance
0,25
0,2
0,15
0,1
0,05
0
400
500
600
700
800
900
Wavelength (nm)
Sandy Soil
Vegetation
Turbid Water with
Suspended Matter
Clear Water

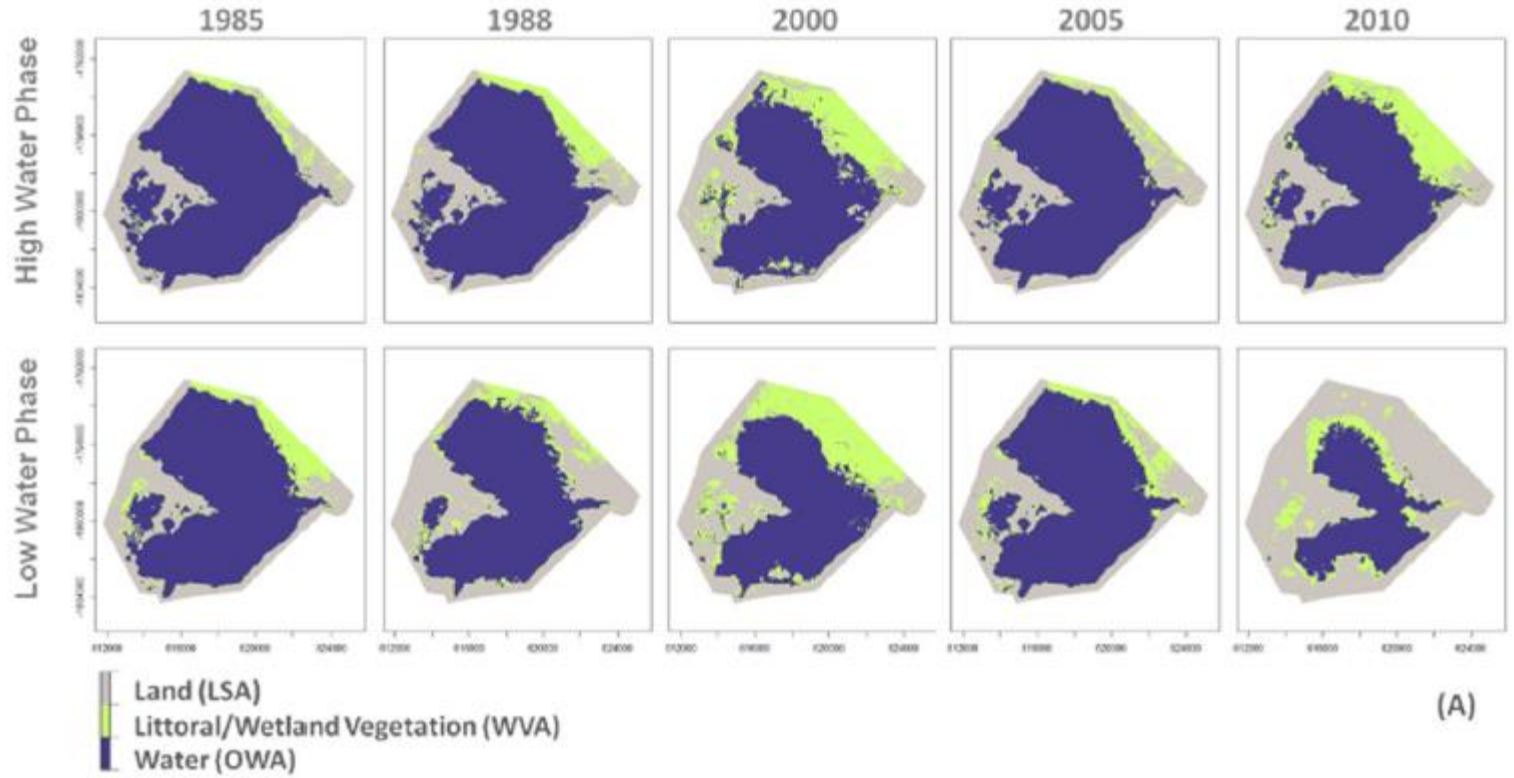



NWI
NDVI
NDWI


NWI raster
NWI > 0 & Getis-Ord Gi (NWI) > 0
false
true
Land
Land Mask
NDVI raster
NDWI raster
Classified Image
NDVI - 0.1 > 0 & NDWI < 0
false
true
Water
Littoral/Wetland
Vegetation



Satellite-derived monthly centre-reduced area anomalies estimated for Chacororé lake surface area (dark grey) and littoral vegetation (light grey), corresponding to the 1984-2011 period.


1985
1988
2000
2005
2010
High Water Phase
Low Water Phase
Land (LSA)
Littoral/Wetland Vegetation (WVA)
Water (OWA)
(A)

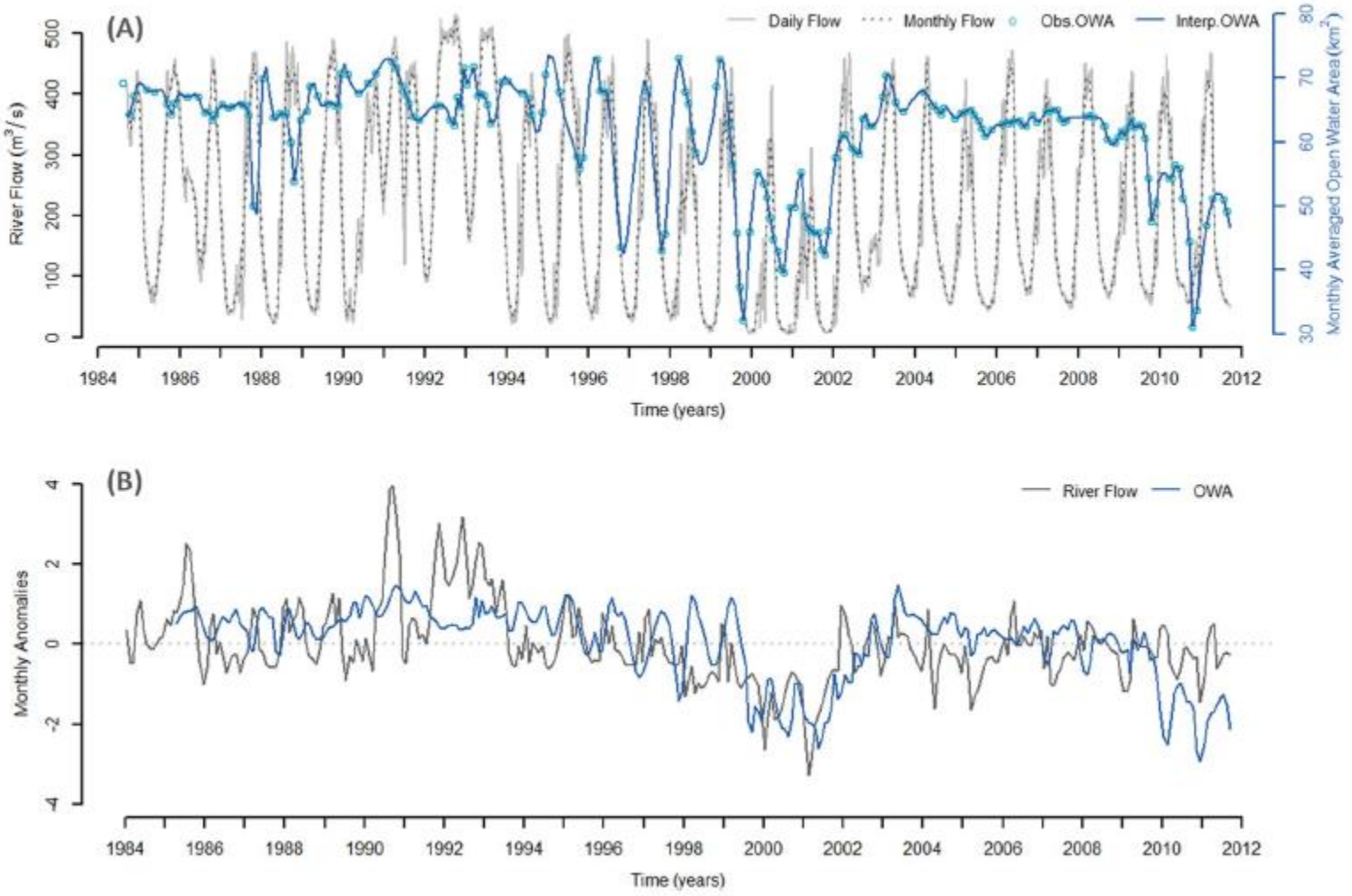
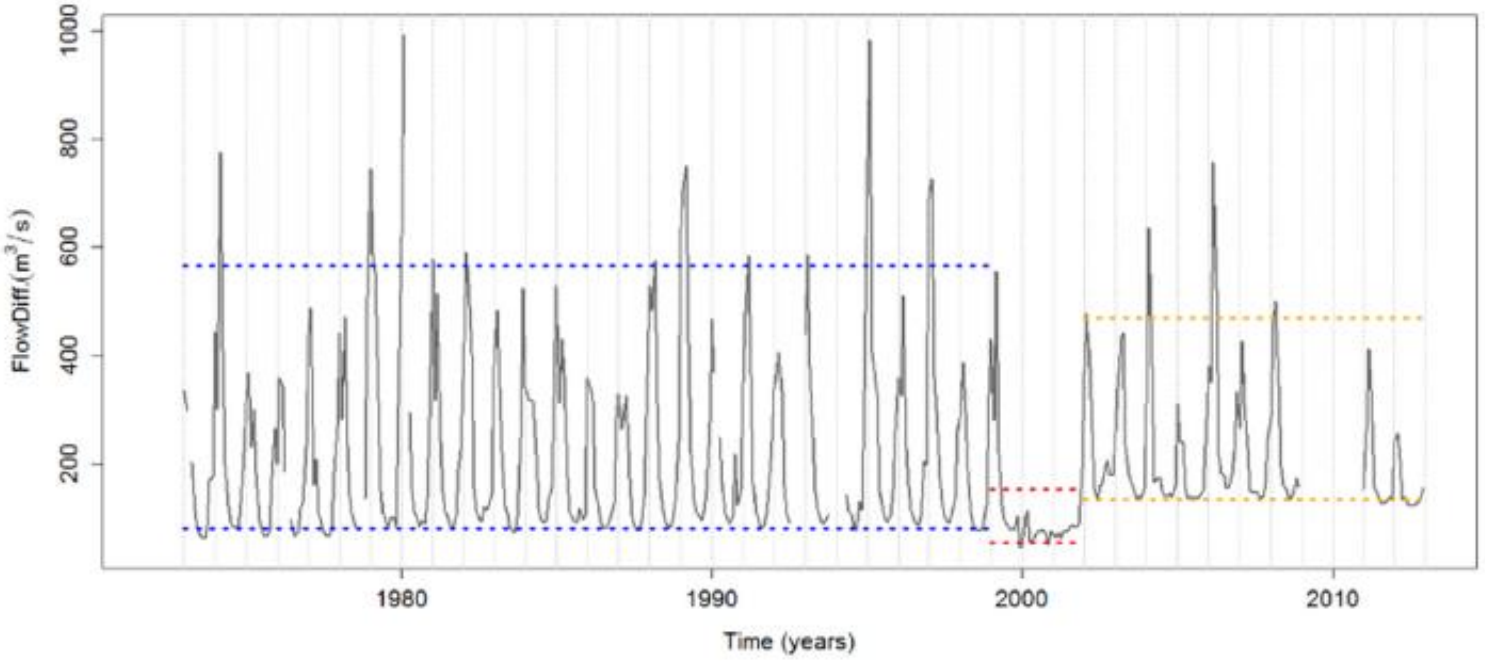

(A)
Daily Flow
Monthly Flow
Obs.OWA
Interp.OWA
River Flow (m^3/s)
Monthly Averaged Open Water Area (km^2)
0
100
200
300
400
500
30
40
50
60
70
80
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Time (years)
(B)
River Flow
OWA
Monthly Anomalies
-4
-2
0
2
4
Time (years)

Table 1
Cross-correlation results (*CCF*) between climate indices (El Niño-3.4; the Oceanic Niño Index: ONI; El Niño MODOKI: EMI; the Trans-Niño Index: TNI; the Multivariate ENSO Index: MEI; the Southern Oscillation Index: SOI; and the Tropical South Atlantic Index: TSA) and Chacororé lake open water area (OWA) anomalies, and wetland vegetation area (WVA) anomalies. All results are statistically significant, with a 95% confidence level.

		NIÑO-3.4	ONI	EMI	TNI	MEI	SOI	TSA
OWA	*CCF*	0.24	0.26	0.45	−0.46	0.31	−0.32	−0.35
	Lag (months)	−1	−1	−1.83	−1.83	−0.75	−0.33	−1.67
WVA	*CCF*	−0.36	−0.24	−0.38	0.47	−0.35	0.36	0.25
	Lag (months)	−0.83	−1	−1.83	−1.83	−0.75	−0.75	−1.58


FlowDiff.(m³/s)
200
400
600
800
1000
1980
1990
2000
2010
Time (years)

Long-term fluctuation modulate by climatic variability and anthropogenic disturbances (Manso reservoir construction) → Littoral herbaceous plant expansion or retraction(not bigger floating plants)

Resilience indicators: prospects and limitations for early warnings of regime shifts

Vasilis Dakos[1], Stephen R. Carpenter[2], Egbert H. van Nes[3] and Marten Scheffer[3]

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[2]Center for Limnology, University of Wisconsin, Madison, WI 53706, USA
[3]Department of Aquatic Ecology and Water Quality Management, Wageningen University, PO Box 47, Wageningen 6700AA, The Netherlands

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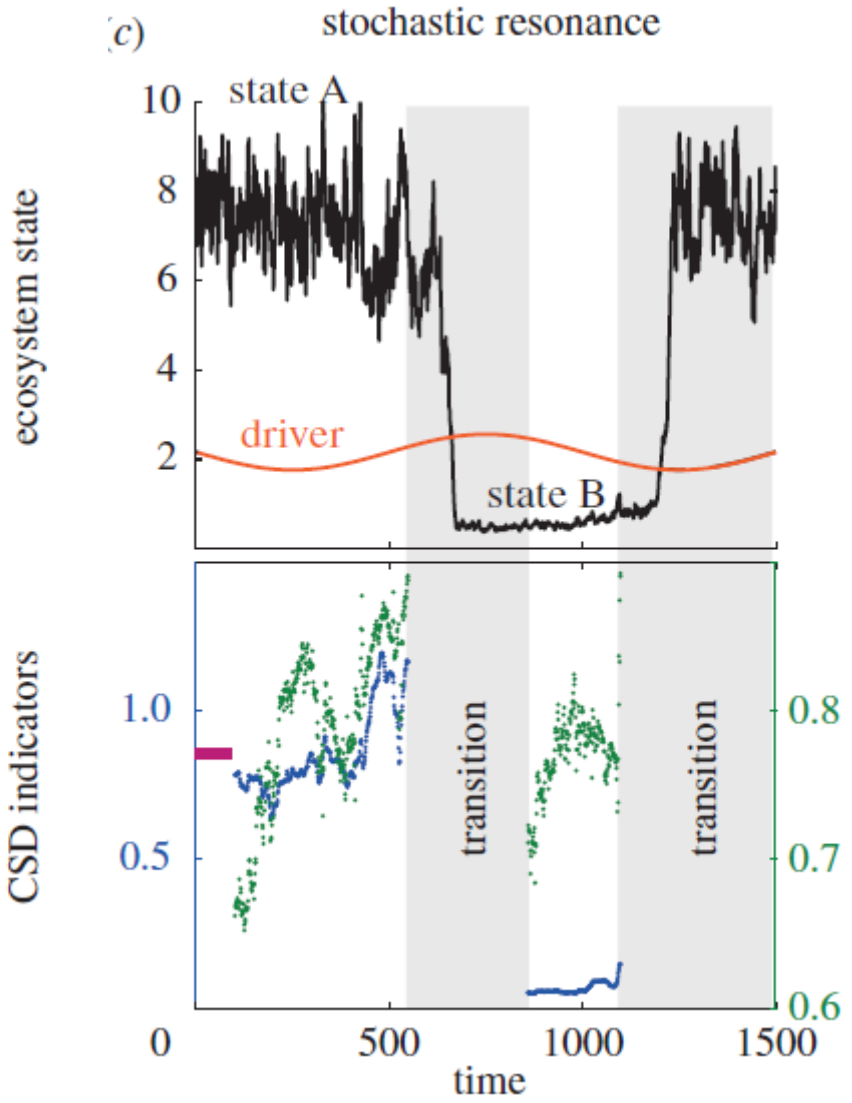

Resilience indicators: prospects and limitations for early warnings of regime shifts

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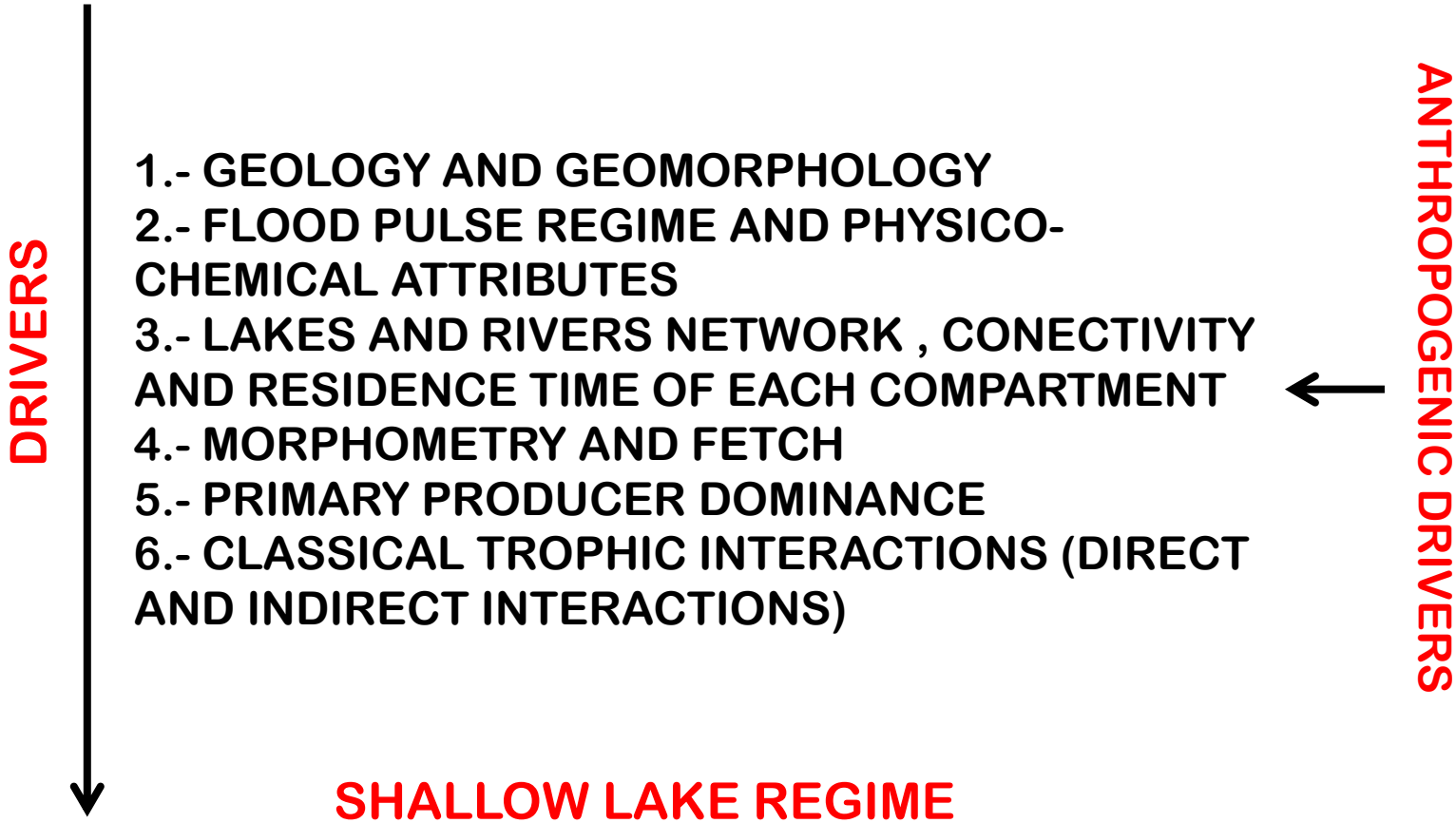
Swinging between alternative regimes can result from a combination of stochastic perturbation and a periodic change in environmental conditions.

Depending on the rate of the processes and the amplitude of the stochastic forcing, it may be difficult to observe increase in variance and autocorrelation prior to the regime shift.

PERSPECTIVES

Pantanal exhibits a complex pattern of ecosystem configurations (or regimes), more complex than the shallow systems outside of floodplain regions.


DRIVERS
1.- GEOLOGY AND GEOMORPHOLOGY
2.- FLOOD PULSE REGIME AND PHYSICO-CHEMICAL ATTRIBUTES
3.- LAKES AND RIVERS NETWORK , CONECTIVITY AND RESIDENCE TIME OF EACH COMPARTMENT
4.- MORPHOMETRY AND FETCH
5.- PRIMARY PRODUCER DOMINANCE
6.- CLASSICAL TROPHIC INTERACTIONS (DIRECT AND INDIRECT INTERACTIONS)
ANTHROPOGENIC DRIVERS
SHALLOW LAKE REGIME

We must to understand the effects of the multiple drivers on the ecosystem configuration and ecosystem services associated:

+ Integrating mechanism-based approaches and time-series analysis.

+ Novel monitoring of data and experimentation

+ Identifying best-candidate ecosystems and promote the systemic perspective.