Restoration of mediterranean-type streams

Principles and implementation

An overview

INTERNATIONAL SYMPOSIUM ON RIVER RESTORATION

Madrid, 19-21 September 2006

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Tel-Aviv University, Israel

mediterranean-type streams (MTS)

- **mediterranean – pertains to climate and ecosystem type**
- **Mediterranean - pertains to the Mediterranean basin**

Lecture scheme

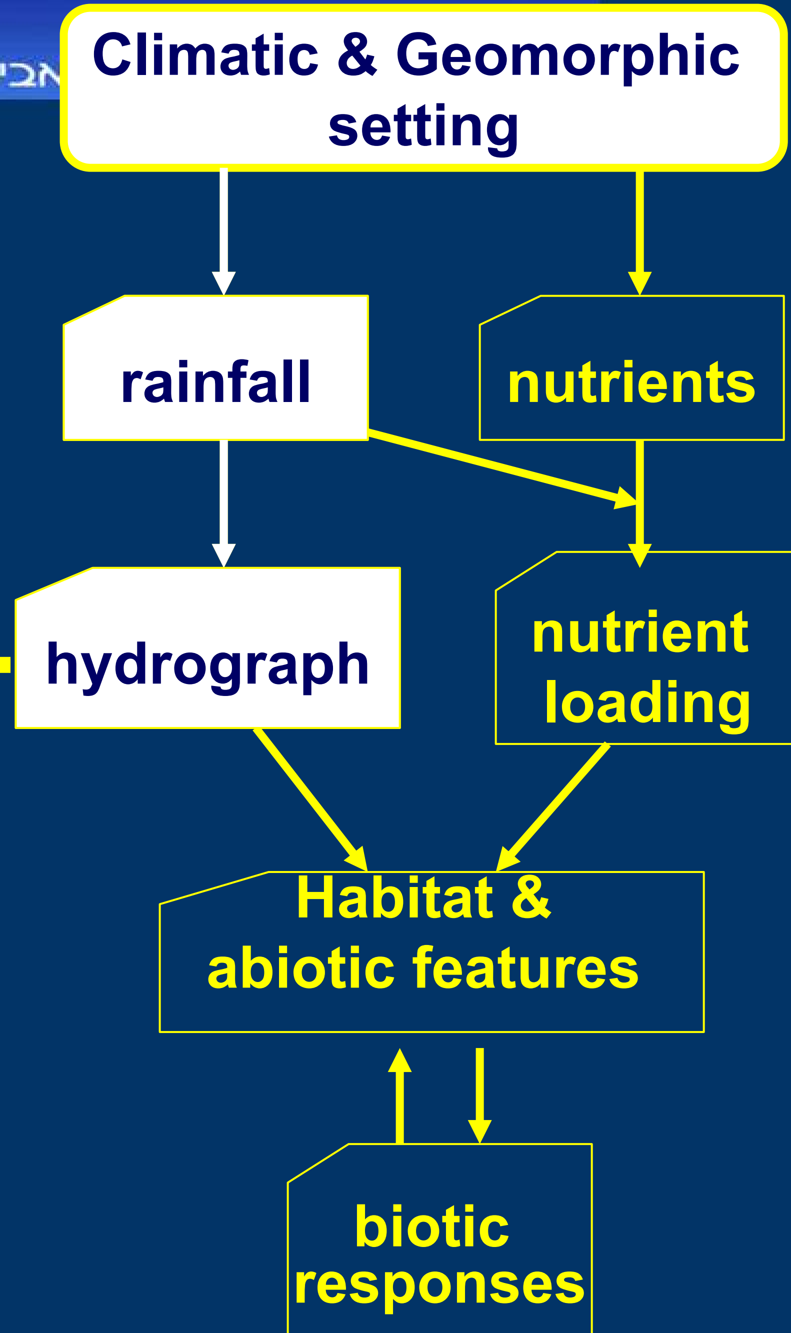
- *Fluvial ecosystems and human impact*
- *Climatic setting*
- *MTS hydrology*
- *MTS hydrology and ecosystem dynamic*
- *Community response in MTS*
  - *to floods*
  - *to drying*
- *MTS hydrology and life history evolution*

- *Restoration*
  - *Definition*
  - *Rehabilitation and competition for water*
  - *implementation*

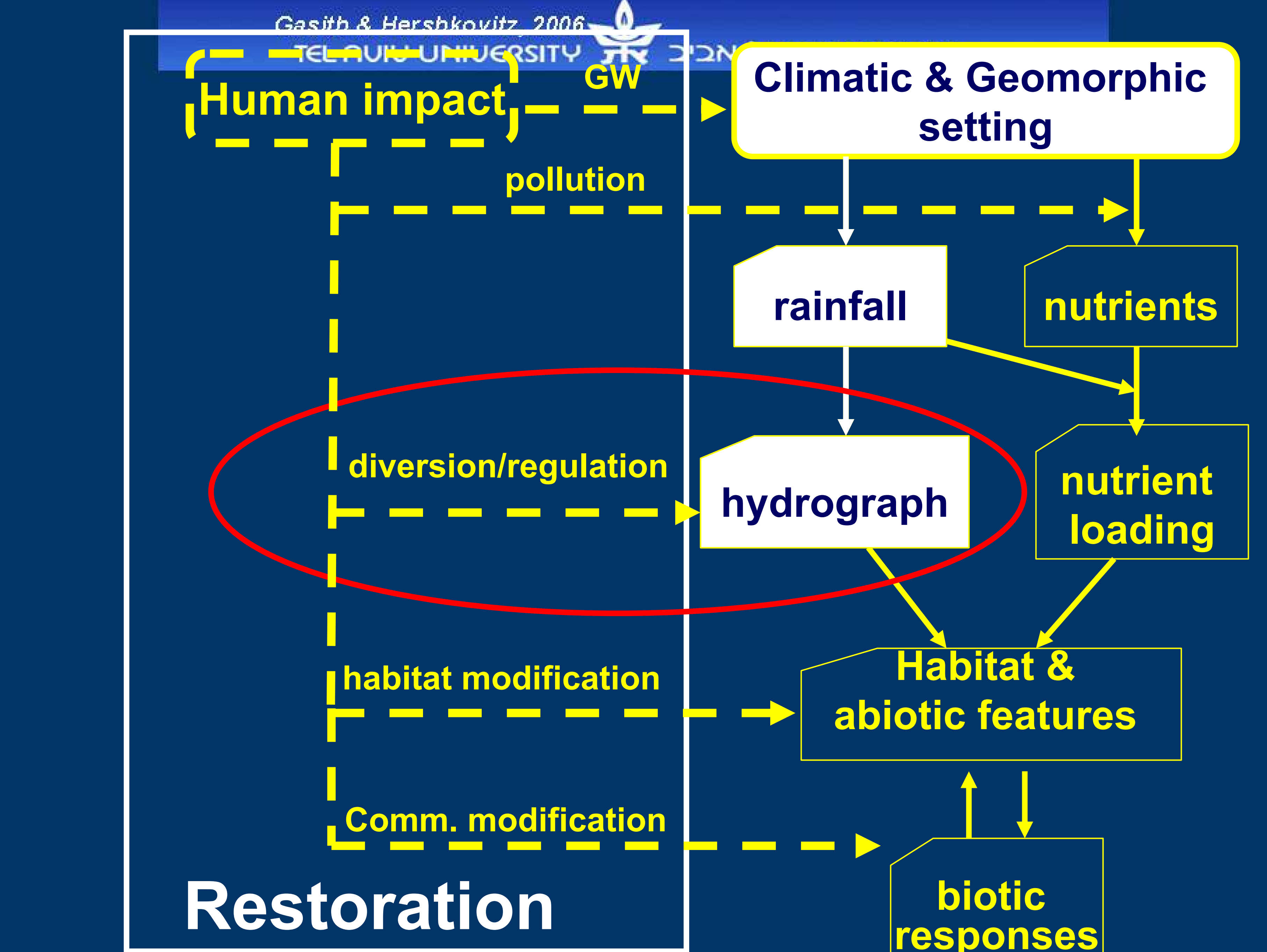
fluvial ecosystems and human impact

fluvial ecosystems

Aniam fall (Gasith)



MTS are defined by their unique hydrologic regime of sequential seasonal, contrasting flows



Gasith & Hershkovitz, 2006
TEL AVIV UNIVERSITY
Human impact
GW
Climatic & Geomorphic setting
pollution
rainfall
nutrients
diversion/regulation
hydrograph
nutrient loading
habitat modification
Habitat & abiotic features
Comm. modification
biotic responses
Restoration

Climatic setting

**mild winter
followed by
dry summer**

Gasith & Hershkovitz, 2006
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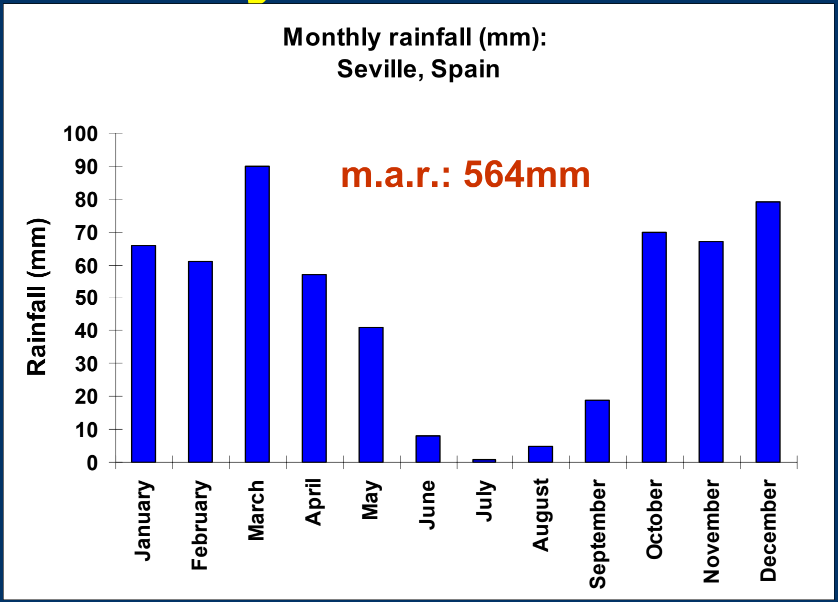
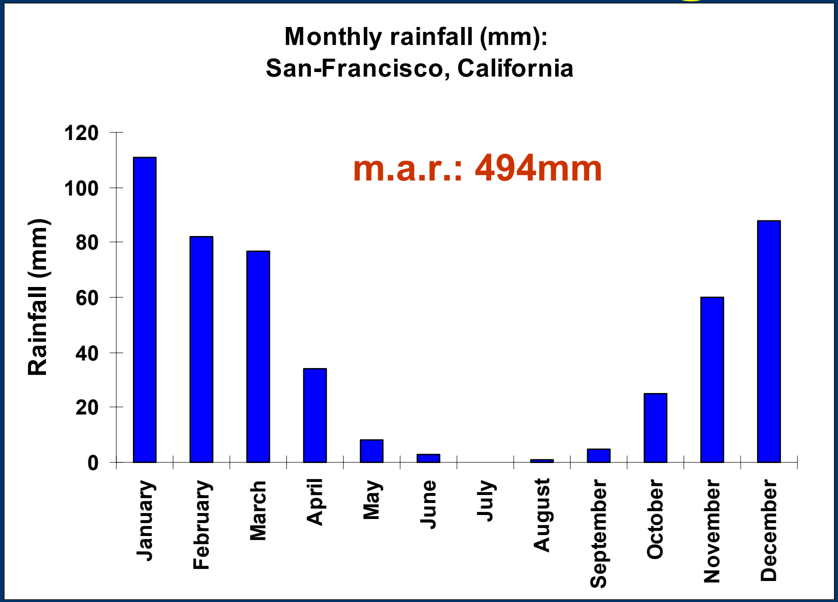
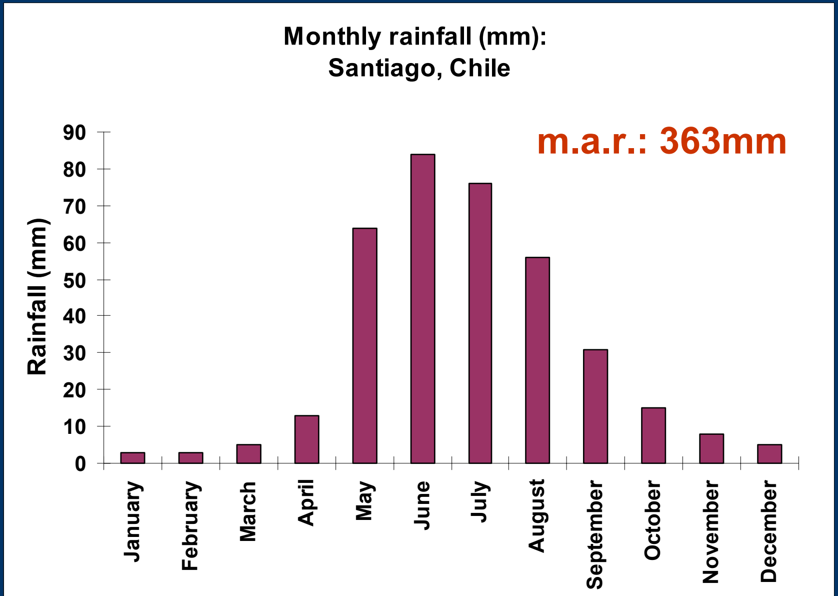
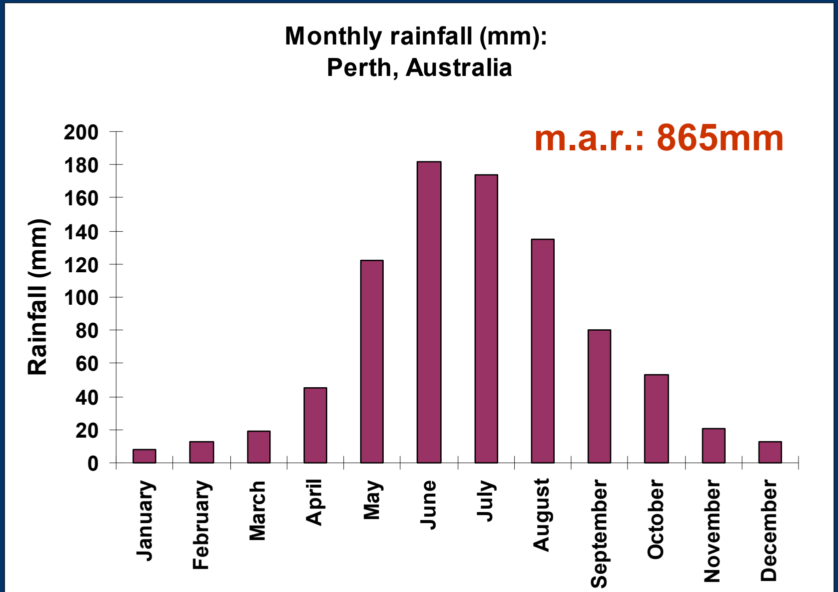
Monthly rainfall in mediterranean-climate regions

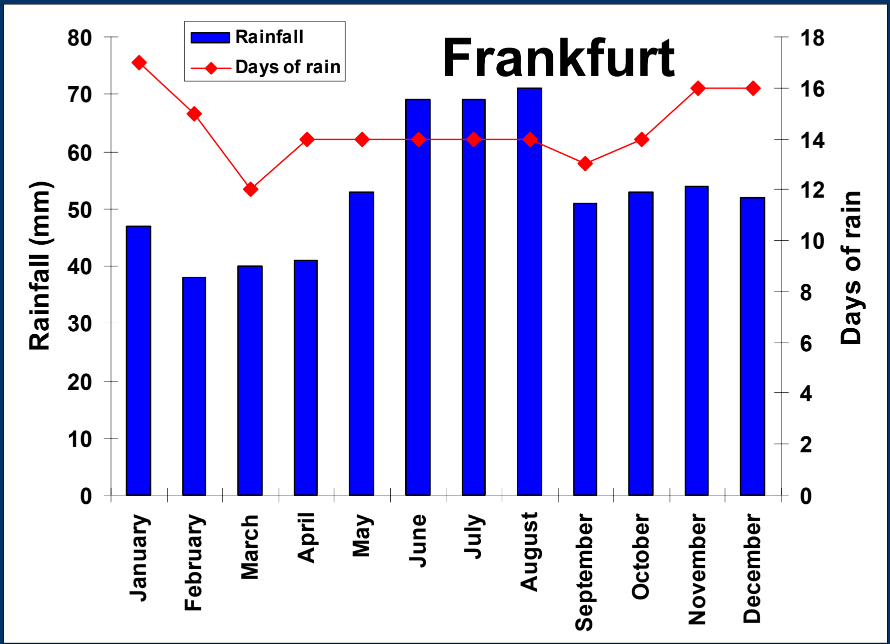


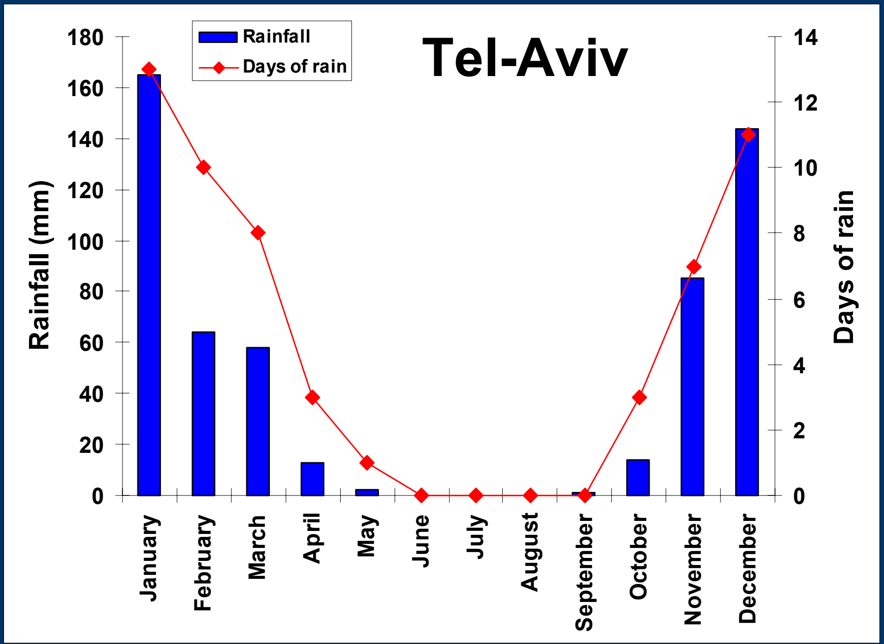






Rainfall pattern in temperate and mediterranean-climate areas



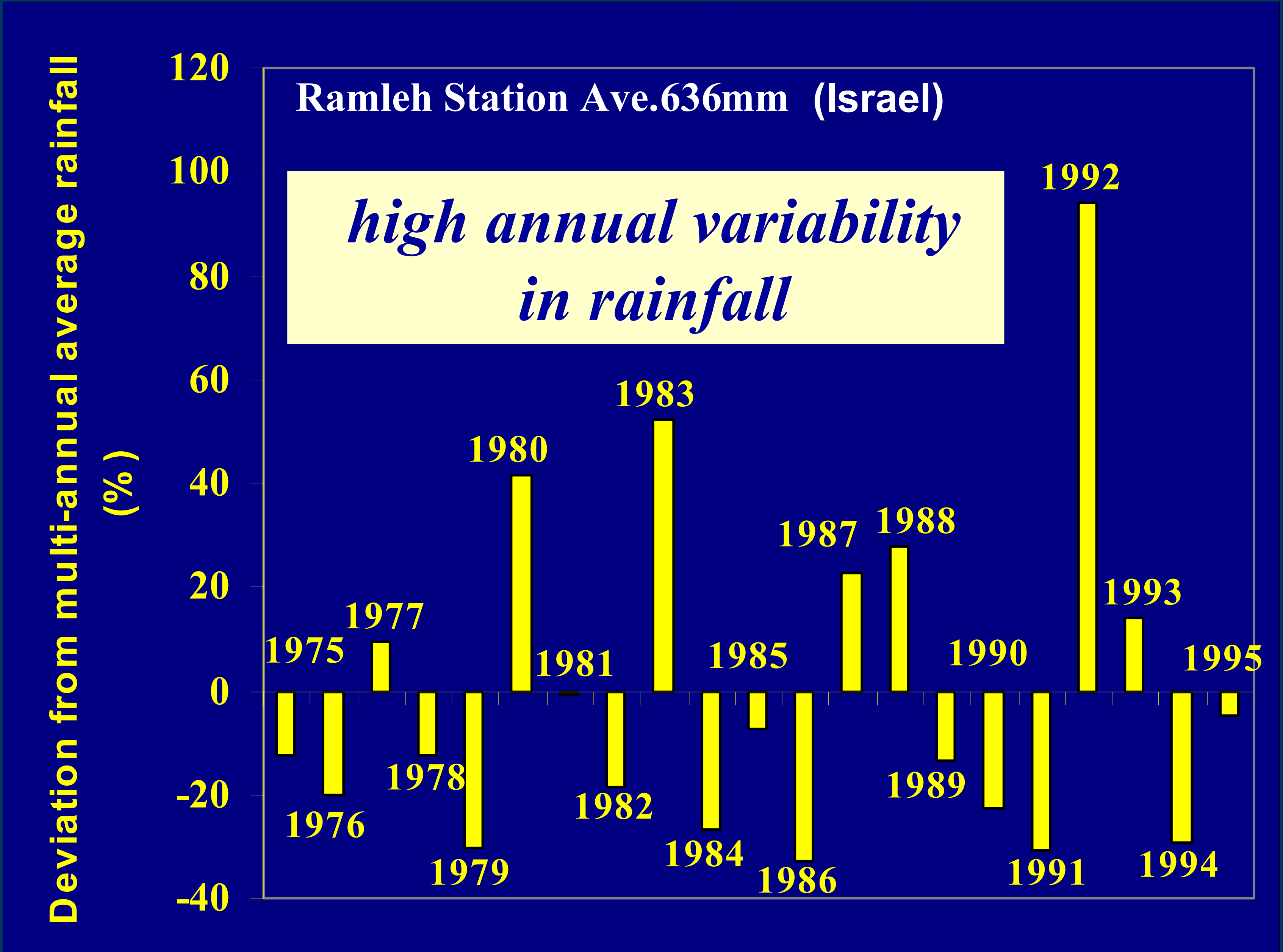


monthly annual rainfall: 638mm

monthly annual rainfall: 546mm

total days of rain: 173

total days of rain: 56


Ramleh Station Ave.636mm (Israel)
high annual variability in rainfall
Deviation from multi-annual average rainfall (%)
120
100
80
60
40
20
0
-20
-40
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
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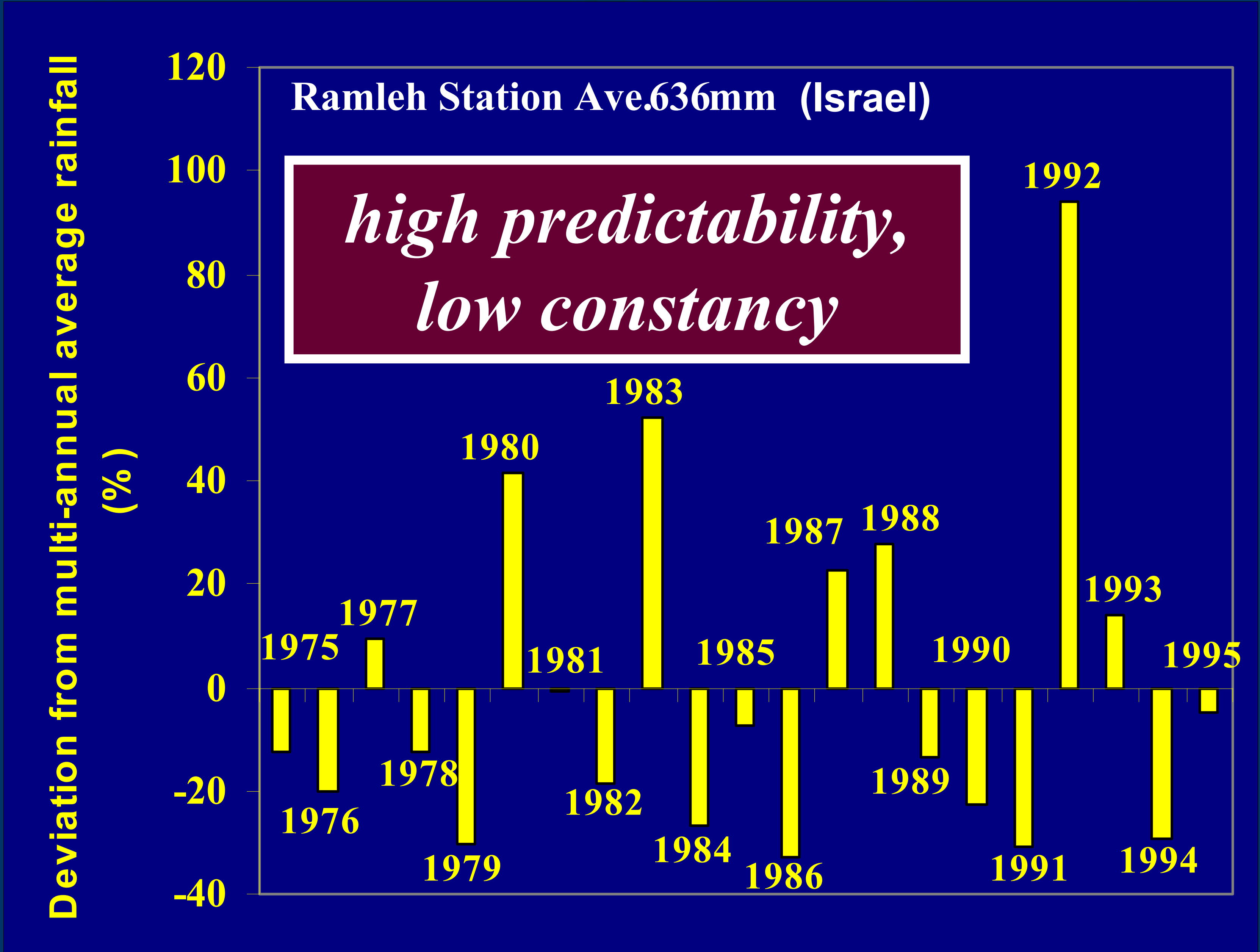
1993
1994
1995


Ramleh Station Ave.636mm (Israel)
high predictability,
low constancy
Deviation from multi-annual average rainfall (%)
120
100
80
60
40
20
0
-20
-40
1975
1976
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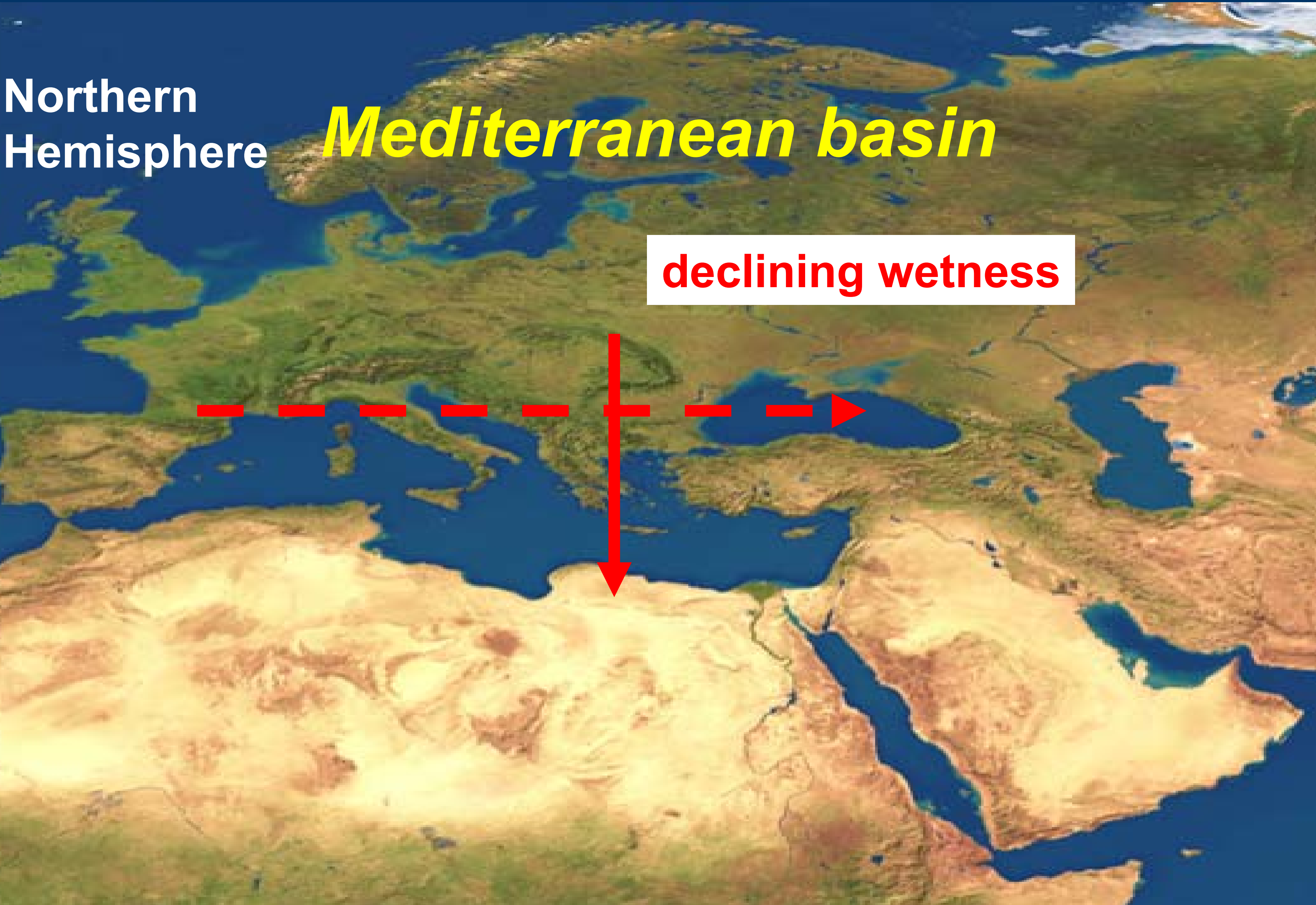
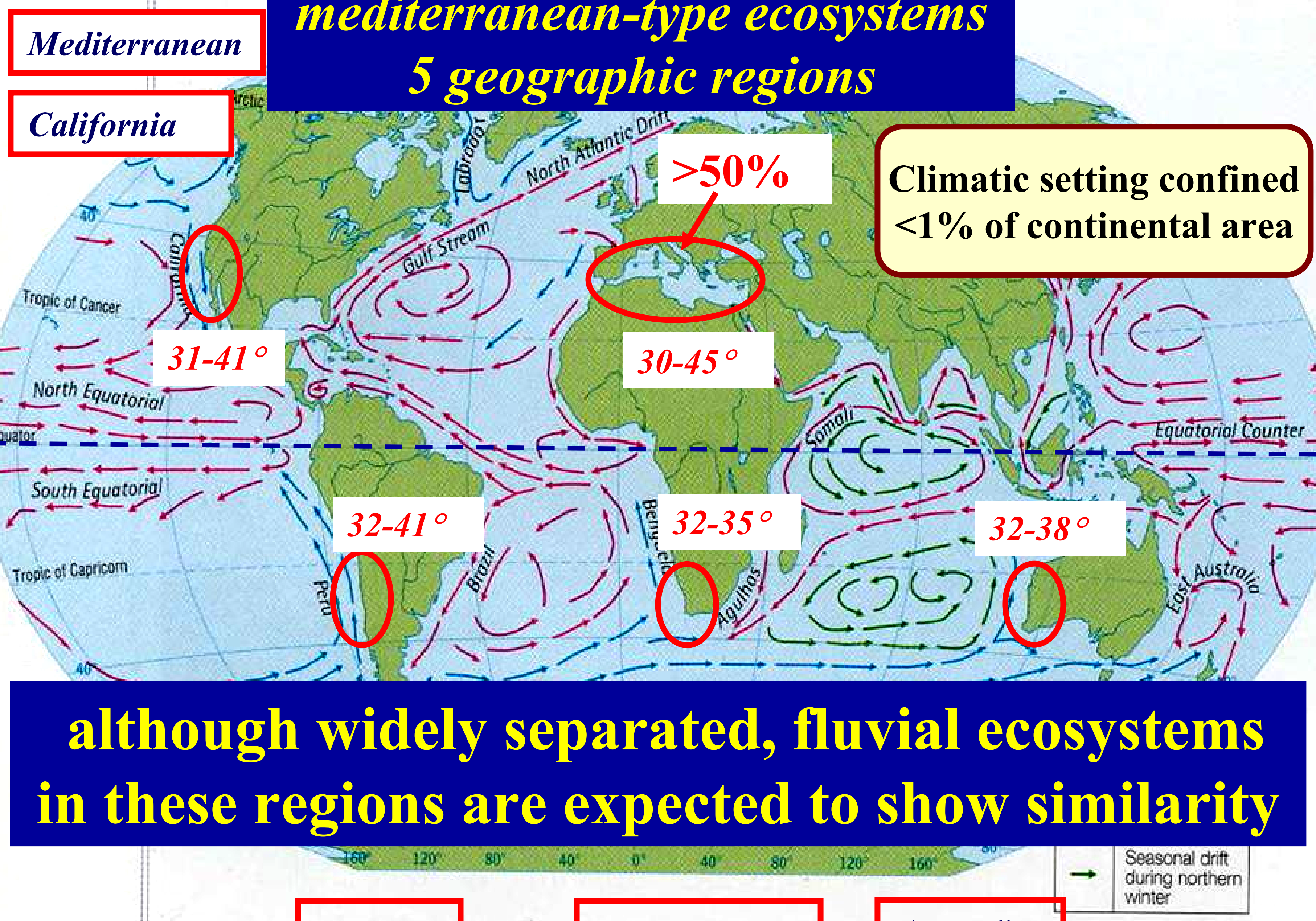

Northern
Hemisphere
Mediterranean basin
declining wetness

mediterranean-type ecosystems
5 geographic regions

Mediterranean

California

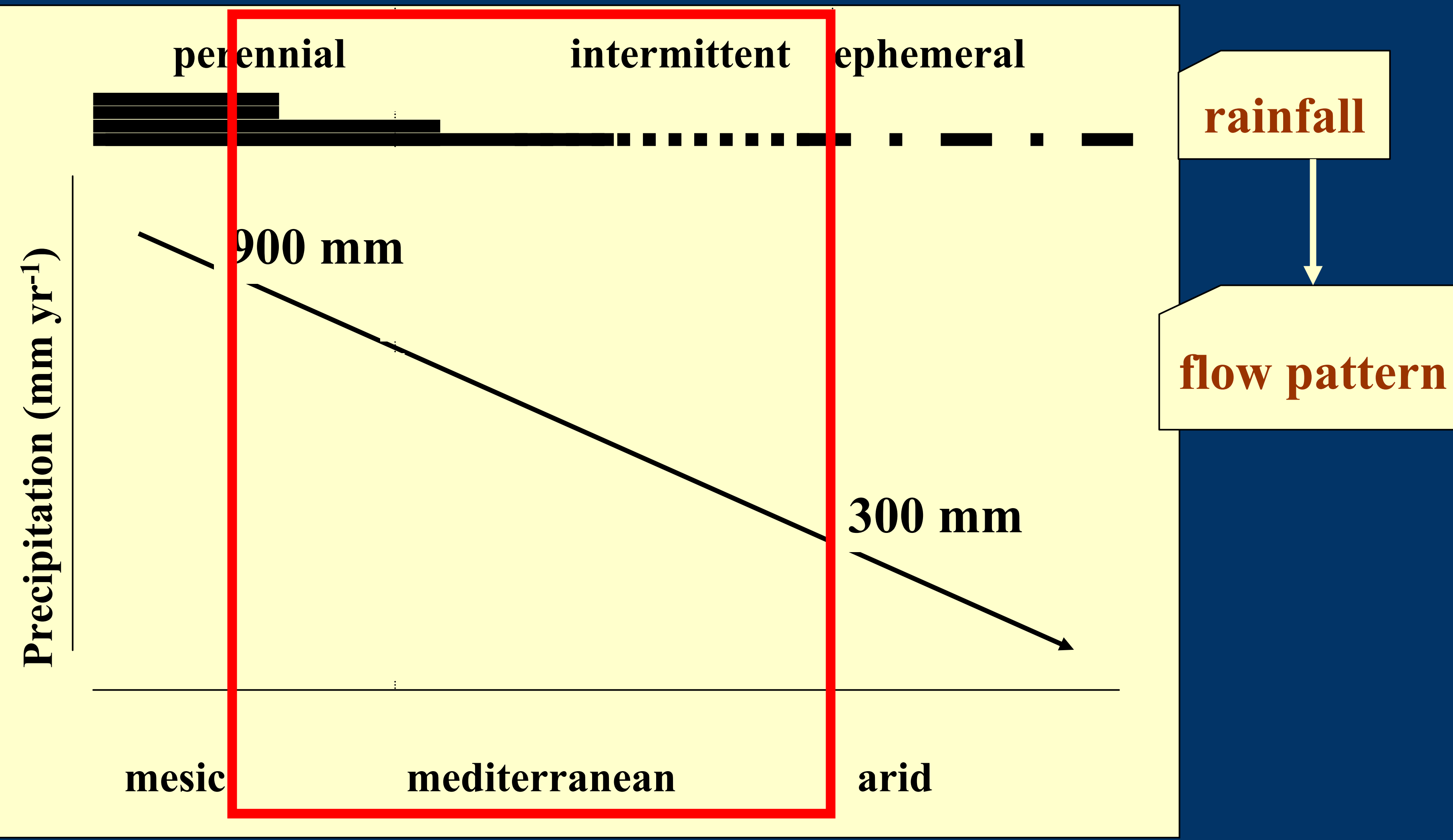
Climatic setting confined <1% of continental area



although widely separated, fluvial ecosystems in these regions are expected to show similarity

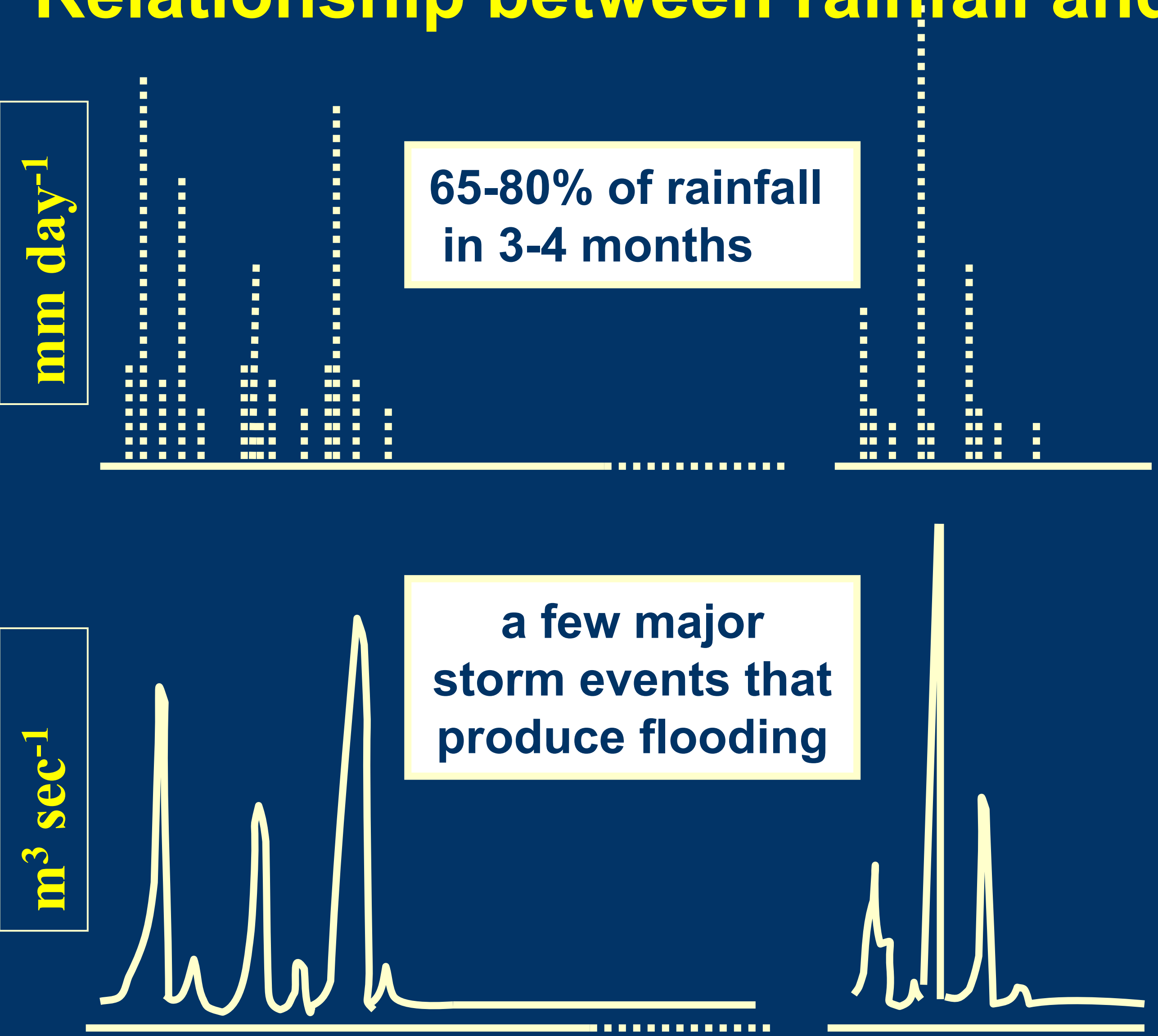
Chile *South Africa* *Australia*

wetness gradient and flow



MTS hydrology

Relationship between rainfall and hydrograph

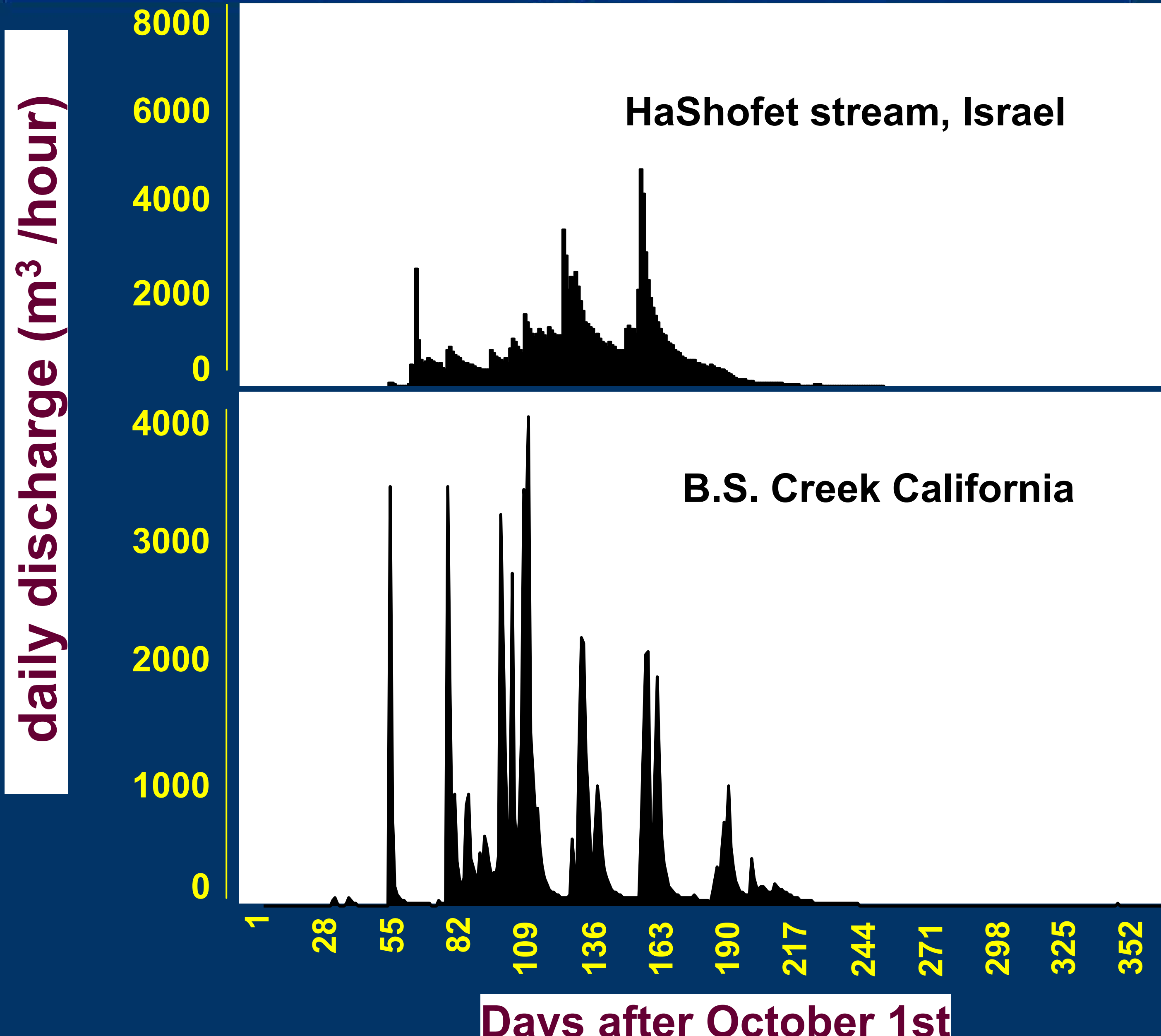


Brief and intense rainstorms

↓

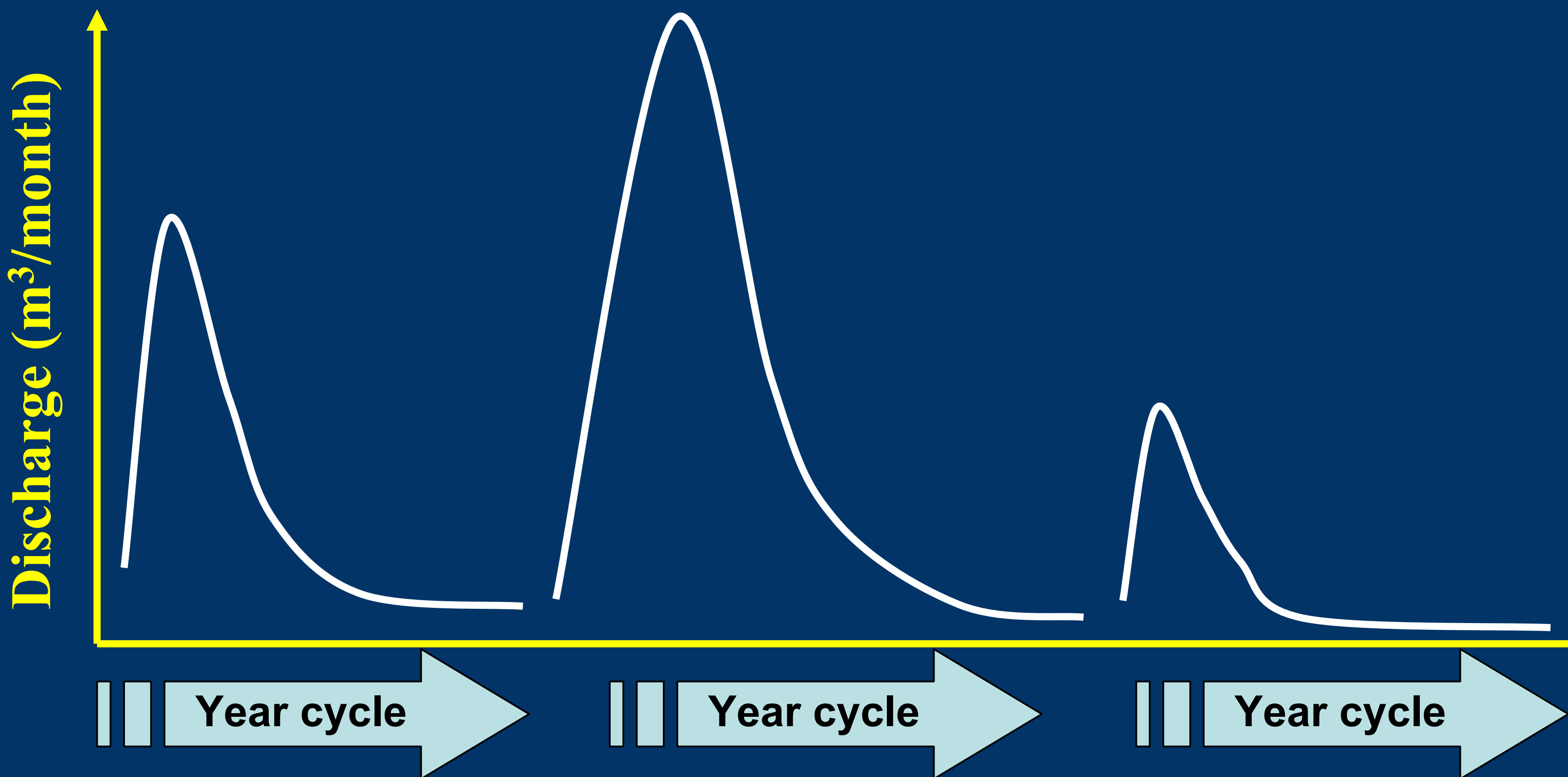
flashy hydrograph (rapid onset and short duration)


Yarmouk river, Israel 3.2.03 (Gasith)
after 2 days of intense rains
strong scour
effect


daily discharge (m3 /hour)
8000
6000
4000
2000
0
HaShofet stream, Israel
4000
3000
2000
1000
0
B.S. Creek California
1
28
55
82
109
136
163
190
217
244
271
298
325
352
Days after October 1st

Fluctuating discharge is a major disturbance and a source of temporal and spatial ecological variation in fluvial ecosystems (Poff et al., 1997)

MTS are shaped by sequential, seasonal predictable disturbances of contrasting flows, that vary markedly in intensity on a multi-annual scale (Gasith and Resh, 1999)




HaShofet stream, Irish brd. Dn (Israel)
winter


HaShofet stream, Irish brd. Dn (Israel)
early summer


HaShofet stream, Irish brd. Dn (Israel)
summer-fall


HaShofet stream, Irish brd. Dn (Israel)
fall

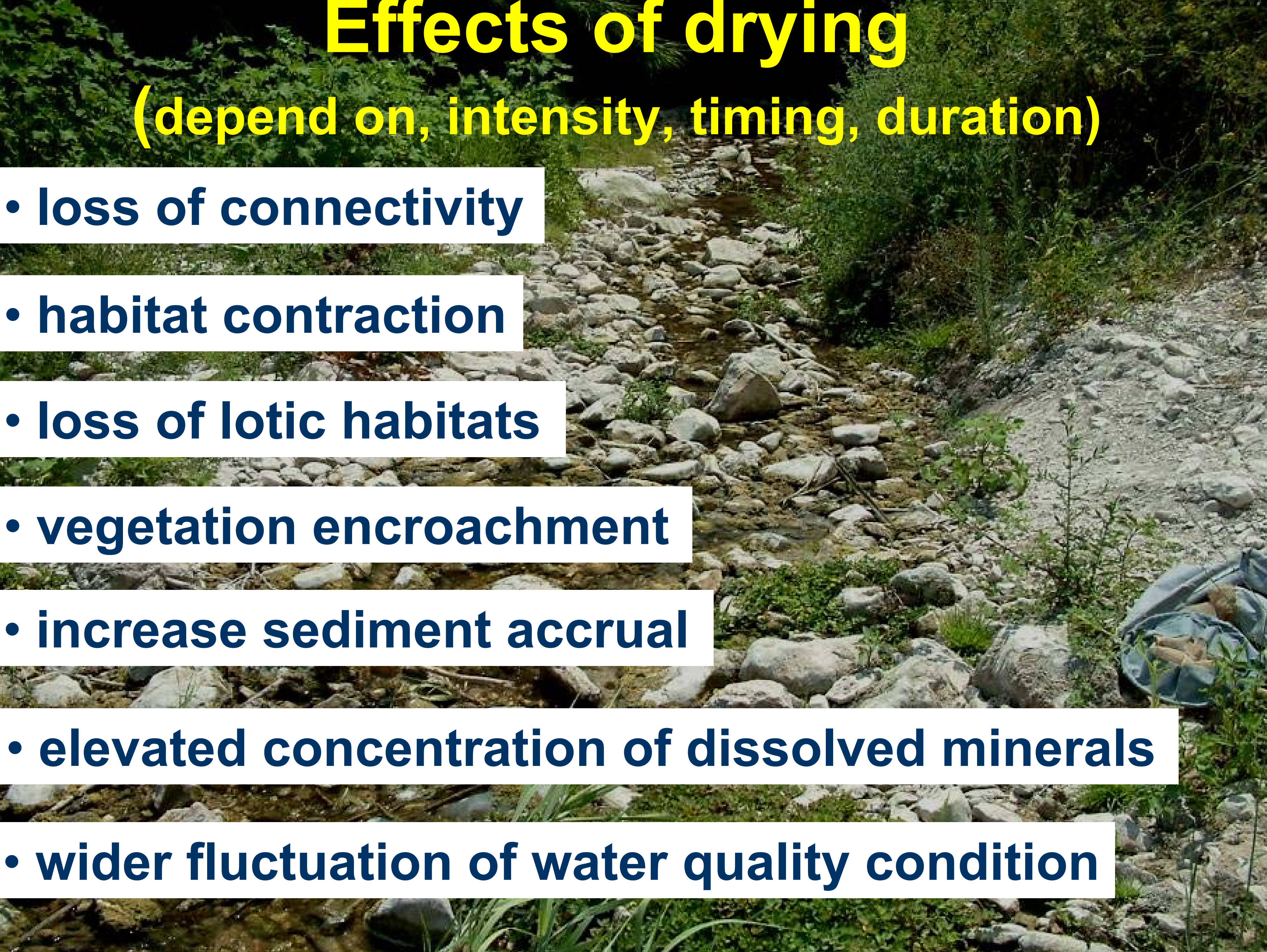
MTS hydrology and ecosystem dynamic

Effects of flood:

(depend on frequency, intensity, timing, duration)

Floods are the yearly “reset mechanism”

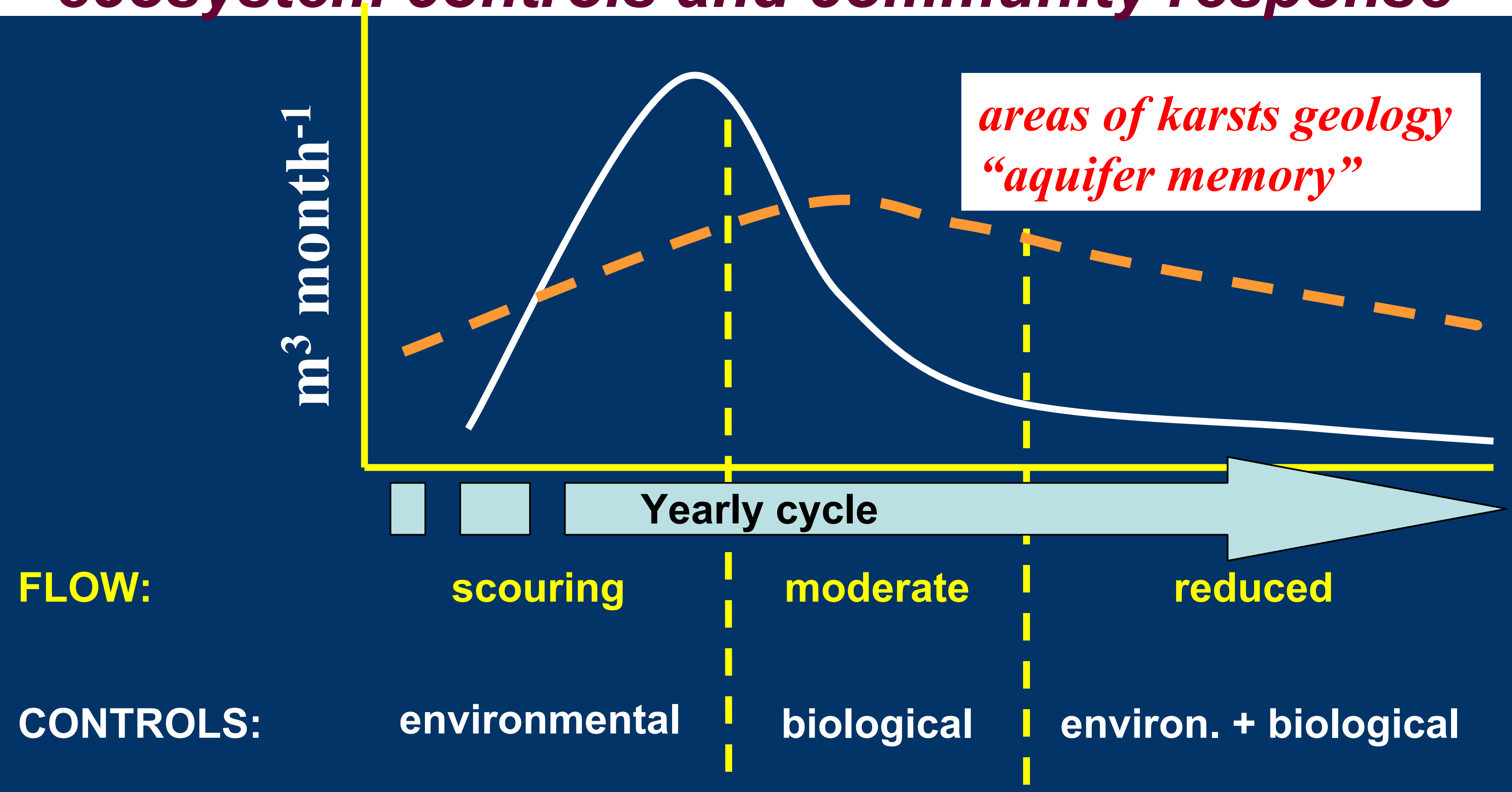
- restoration of channel connectivity
- modification of channel morphology
- restructuring and expansion of habitats
- homogenizing water quality conditions
- redistribution of materials and biota



Effects of drying
(depend on, intensity, timing, duration)

- loss of connectivity
- habitat contraction
- loss of lotic habitats
- vegetation encroachment
- increase sediment accrual
- elevated concentration of dissolved minerals
- wider fluctuation of water quality condition

Proposed relationship between flow intensity, and ecosystem controls and community response



contrasting flow pattern is often most pronounced in intermittent streams

Examples of strong biological control during spring and early summer

ecosystem engineering

by water cress (Nasturtium officinale)

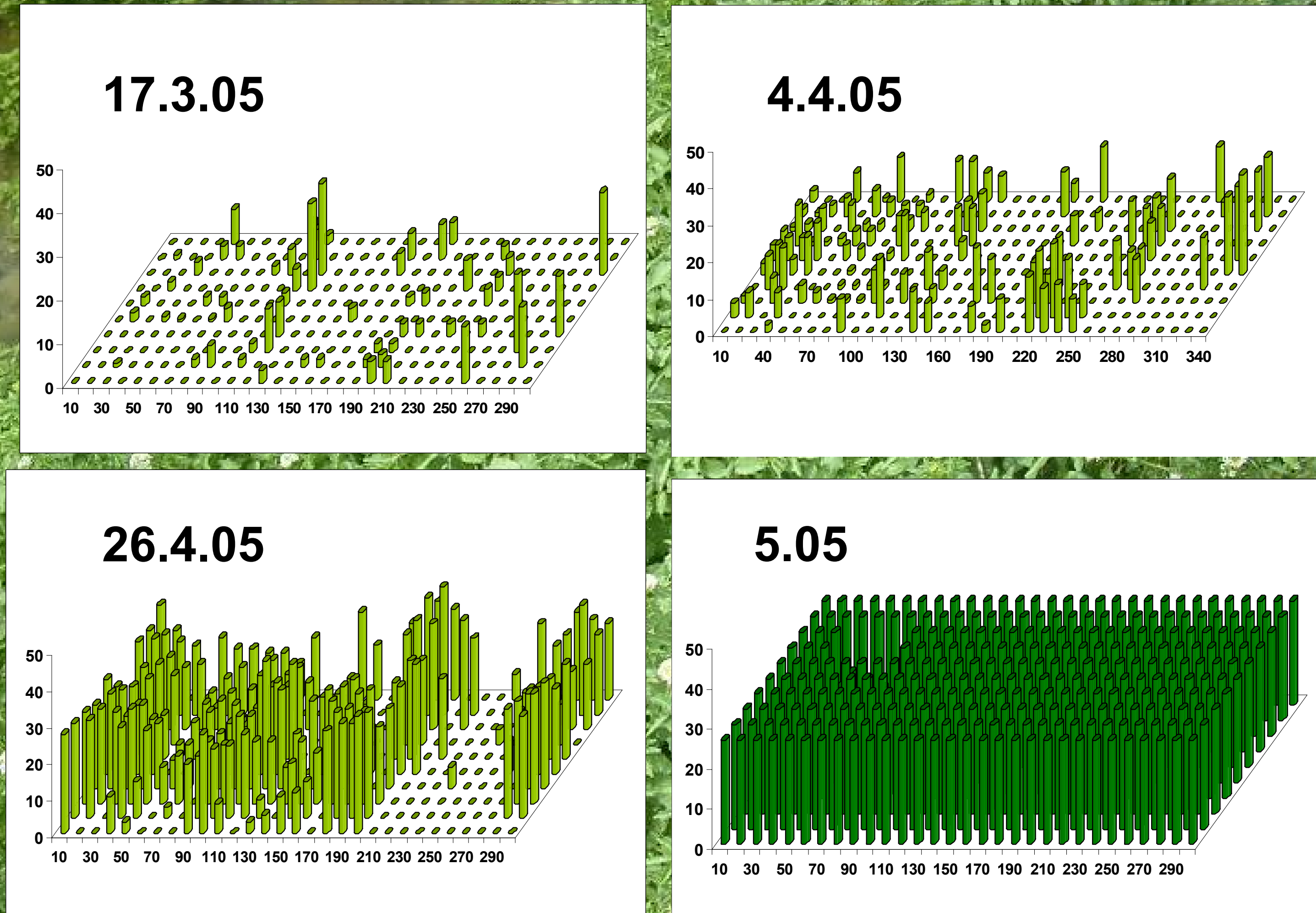
(Hershkovitz and Gasith, in preparation)

Spring - early summer dynamic of in-stream vegetation




Patch dynamic of water cress (Nasturtium officinale)

Plant height (under water) - cm



Channel width - cm

macrophytes

resource modulation

Ecosystem Engineering

stream resources	
metabolic	**non-metabolic**
availability of OM	physical complexity
availability of nutrient	flow velocity
	light and temperature
	oxygen regime

Gasith & Hershkovitz, 2006
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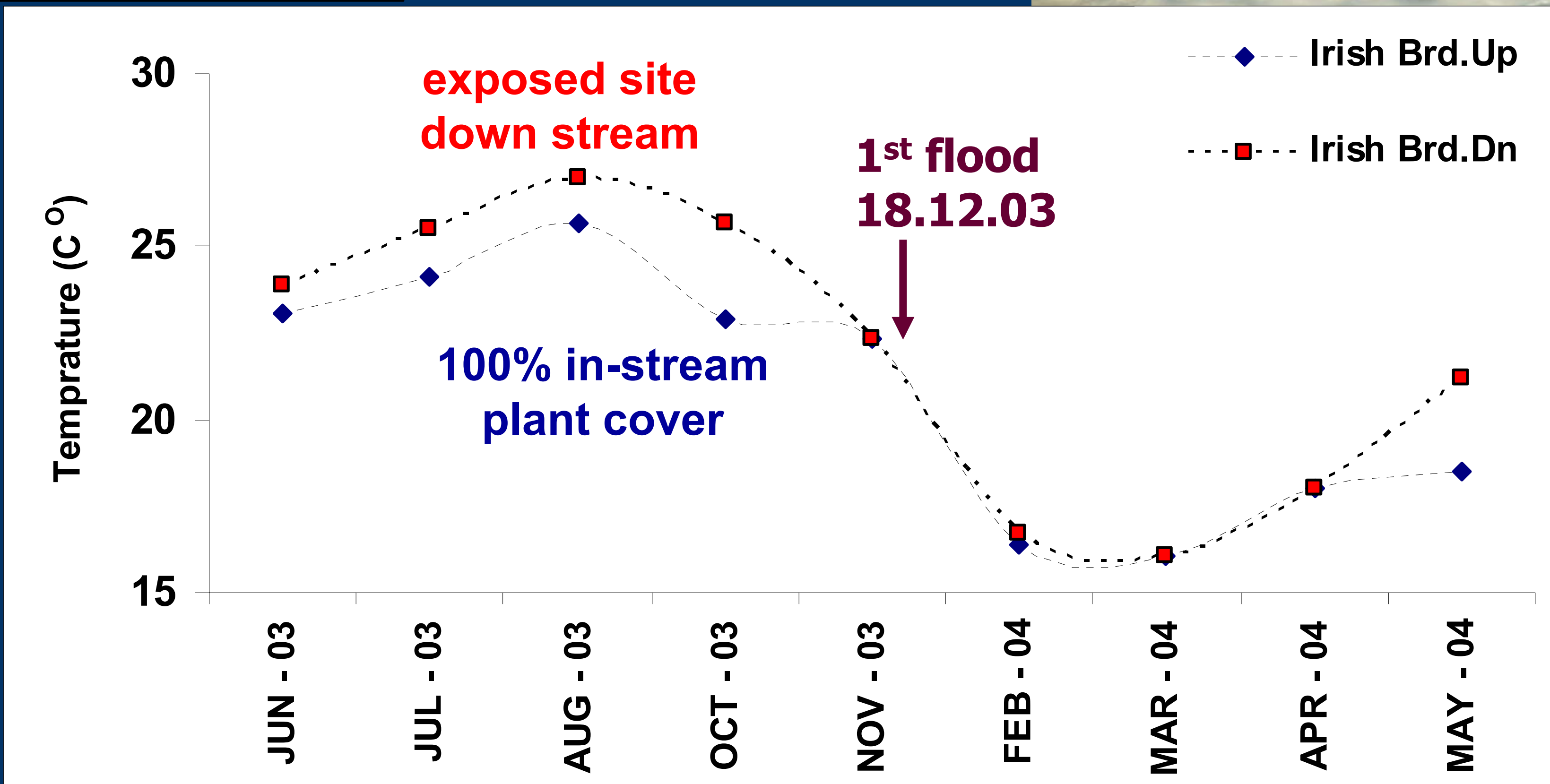
Water temperature dynamic at two adjacent sites

Ha'Shofet stream (Israel)

20 m. downstream



Gasith & Hershkovitz, 2006
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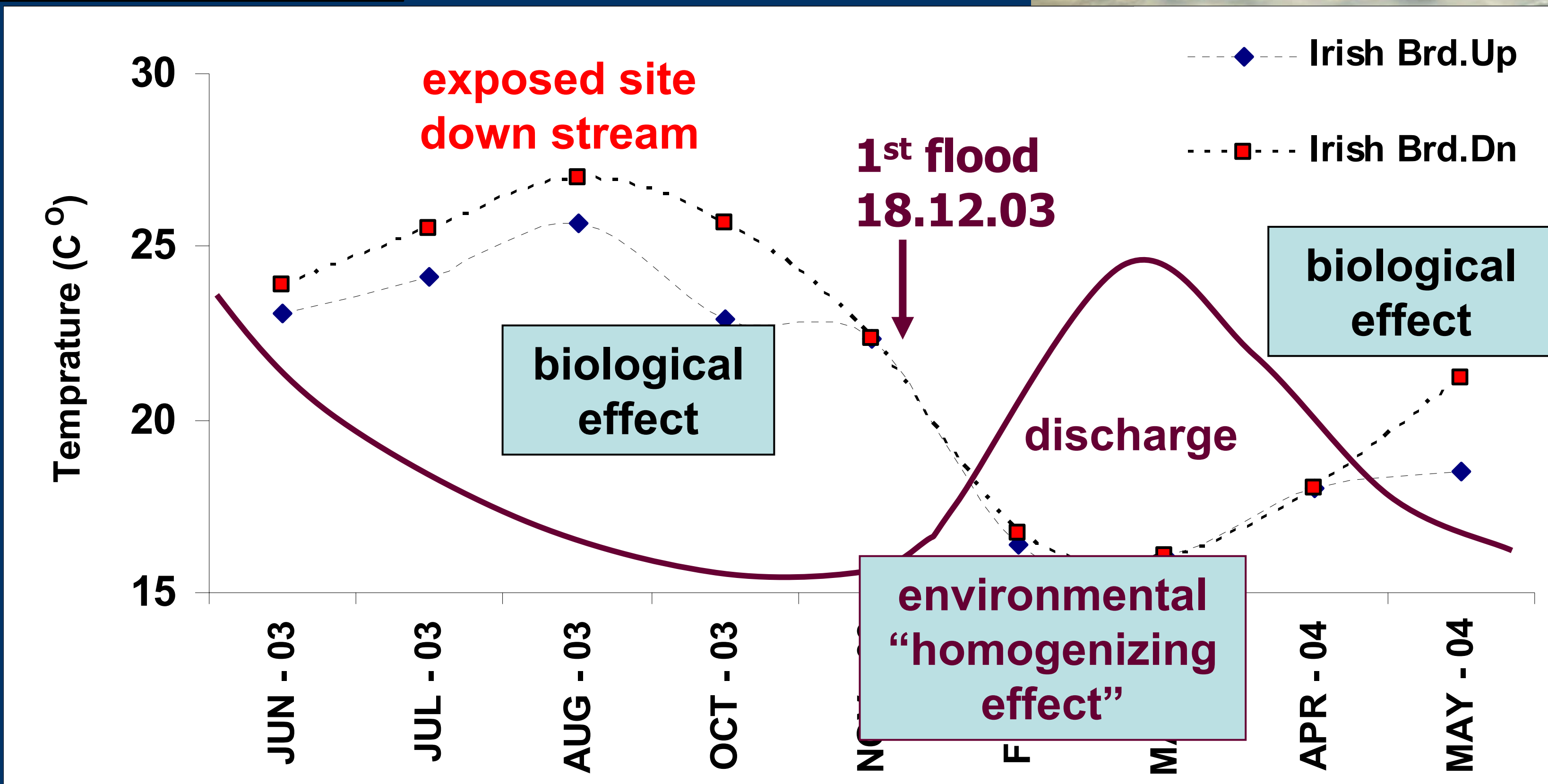
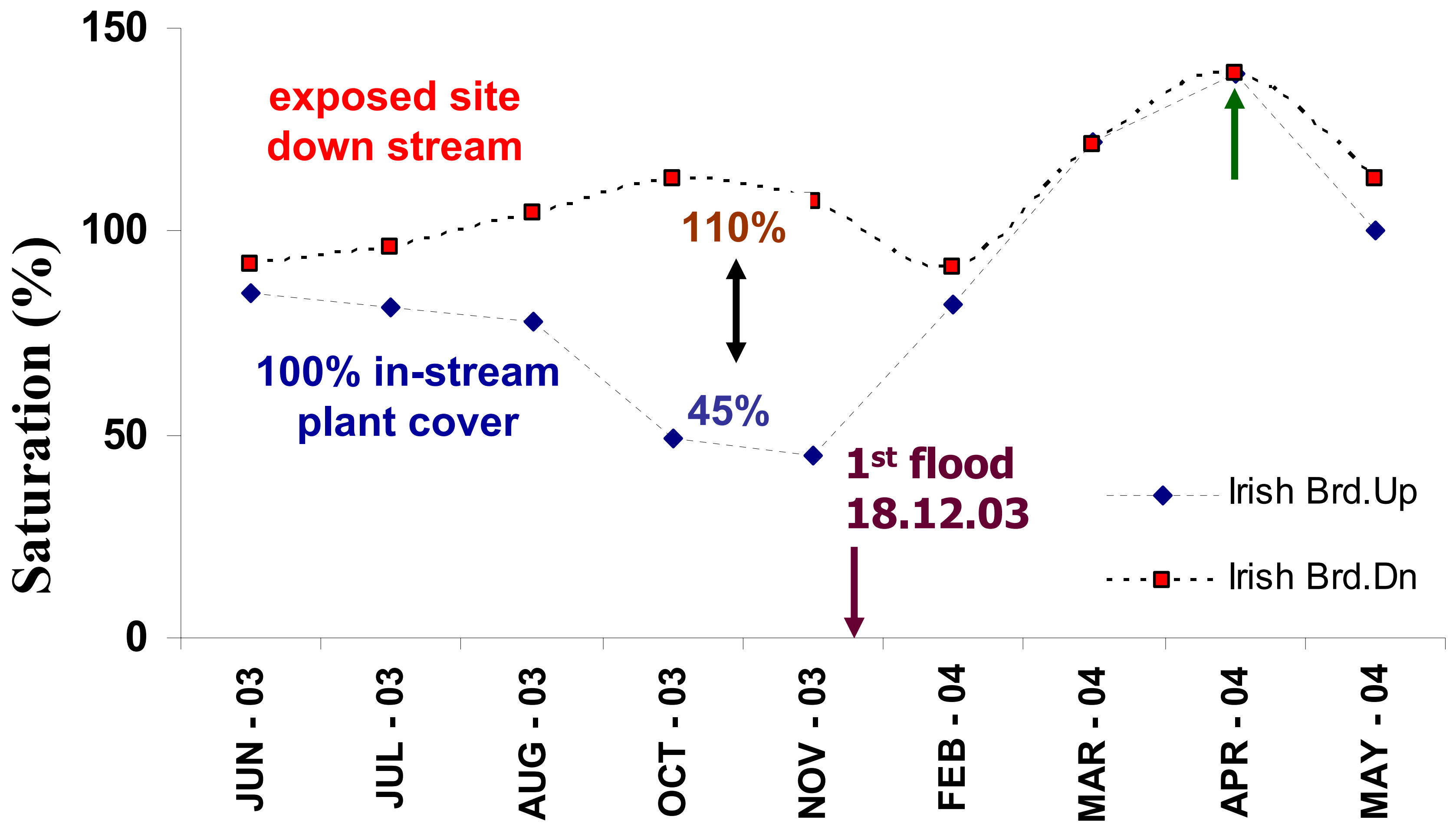


Oxygen dynamic at two adjacent sites

Ha'Shofet stream (Israel)

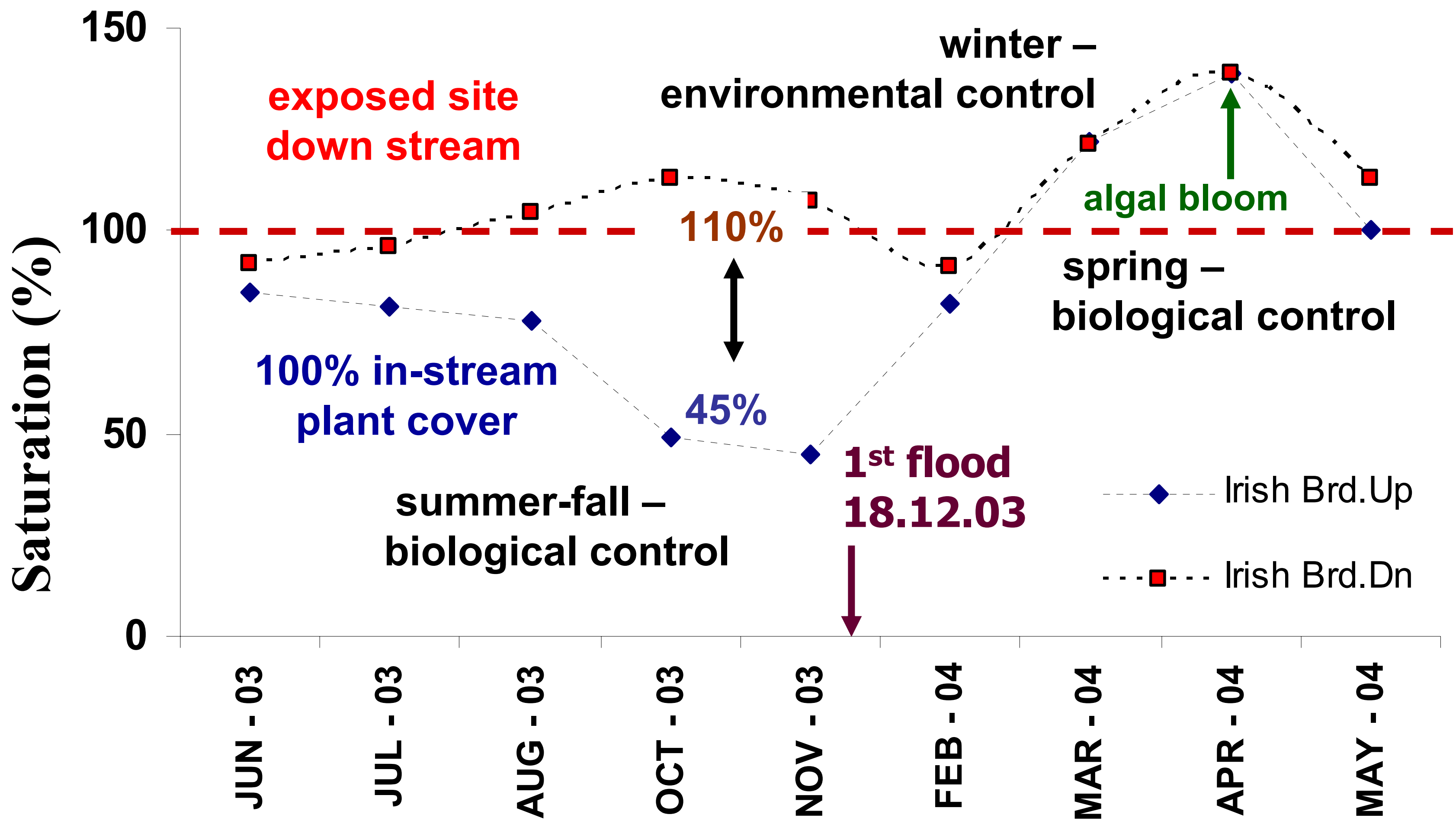
20 m. downstream



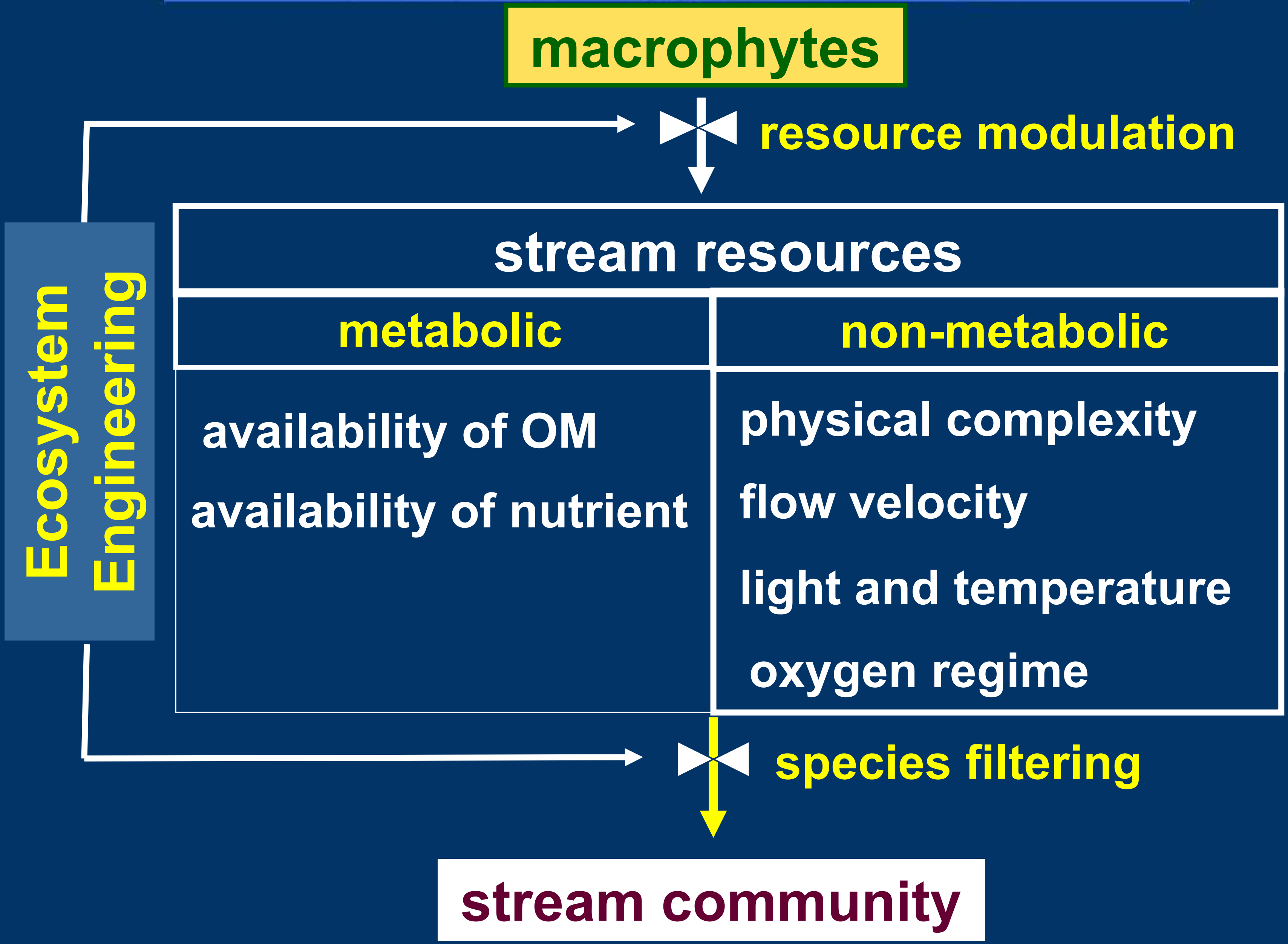
Oxygen dynamic at two adjacent sites

Ha'Shofet stream (Israel)

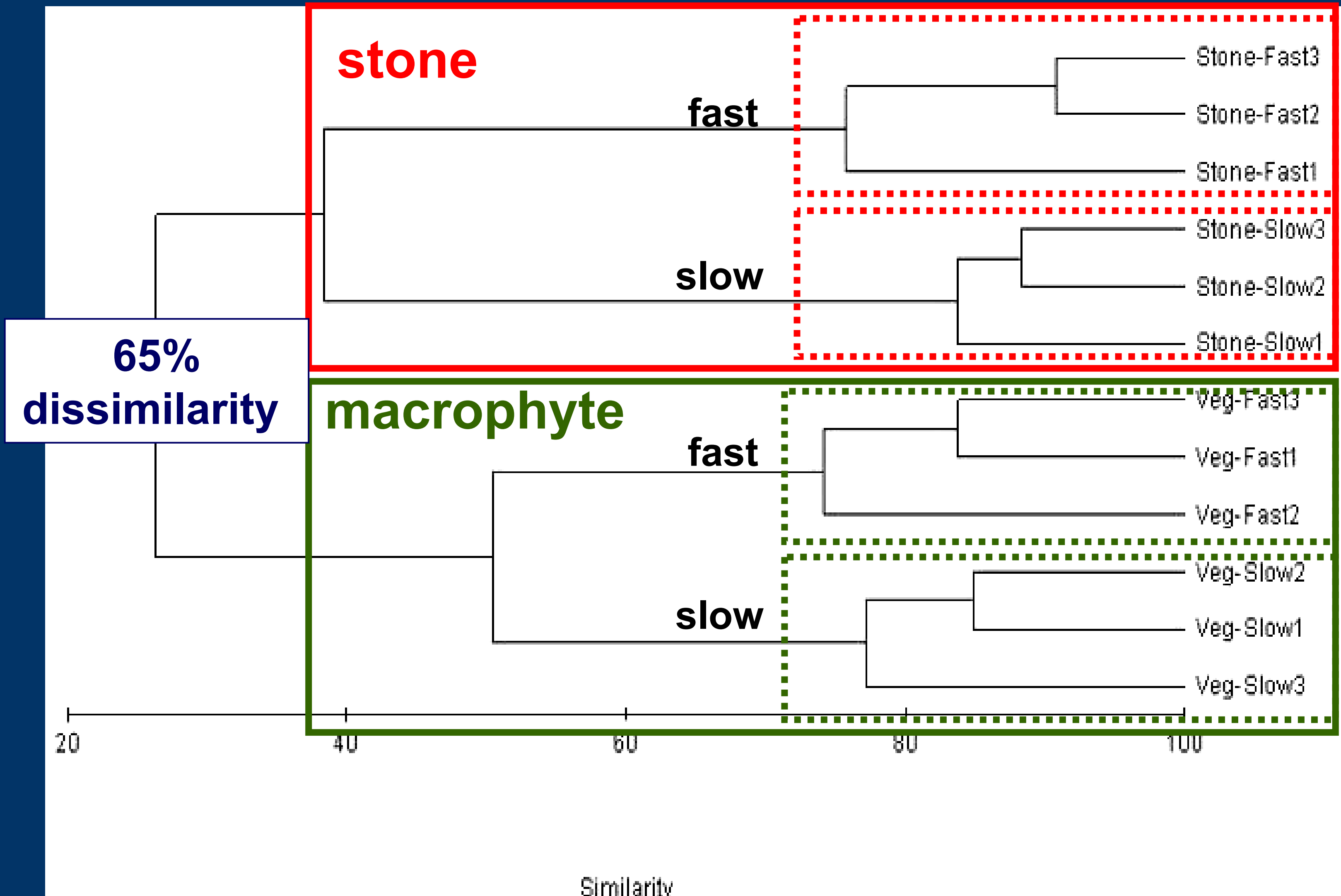
20 m. downstream



Gasith & Hershkovitz, 2006
TEL AVIV UNIVERSITY אוניברסיטת תל-אביב



Effect of macrophytes on macroinvertebrates composition, July 2005 (Bray-Curtis similarity dendrogram of proportions)

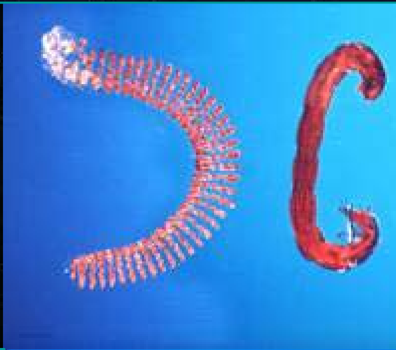


Community response to floods in MTS

Macroinvertebrates richness and density

Gasith & Hershkovitz, 2006
TEL AVIV UNIVERSITY


Most of the information on community response to flooding and drying in MTS is based on macroinvertebrate studies

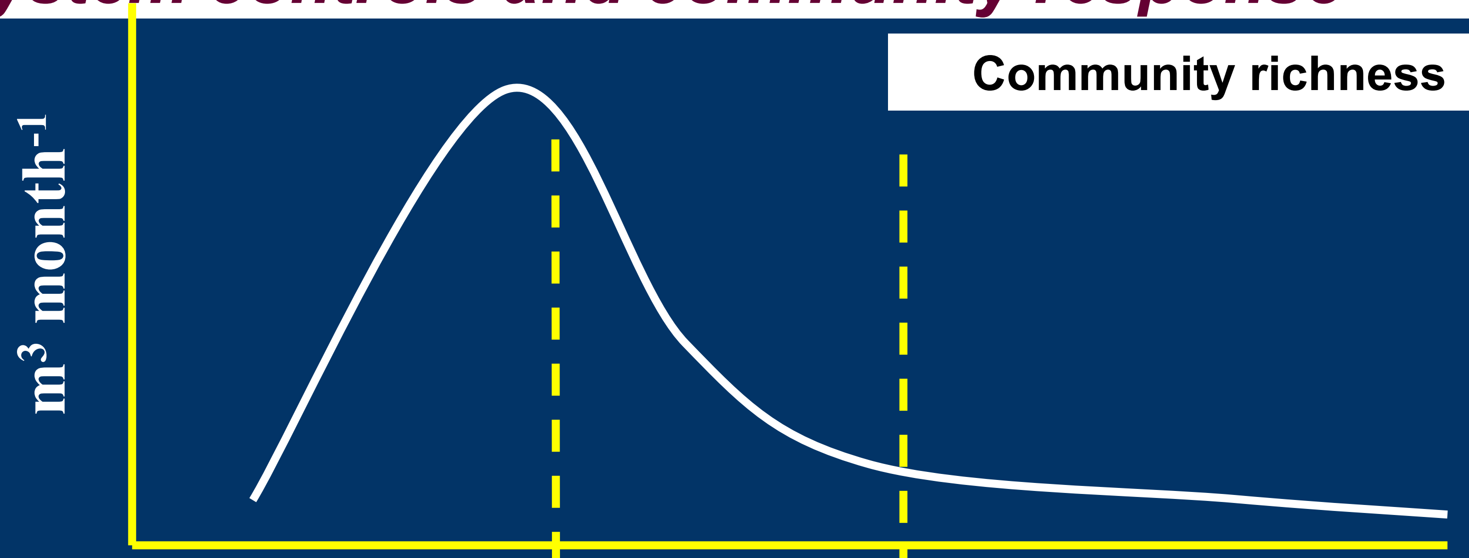
Photos: Shub, Gasith and Hershkovitz, TAU







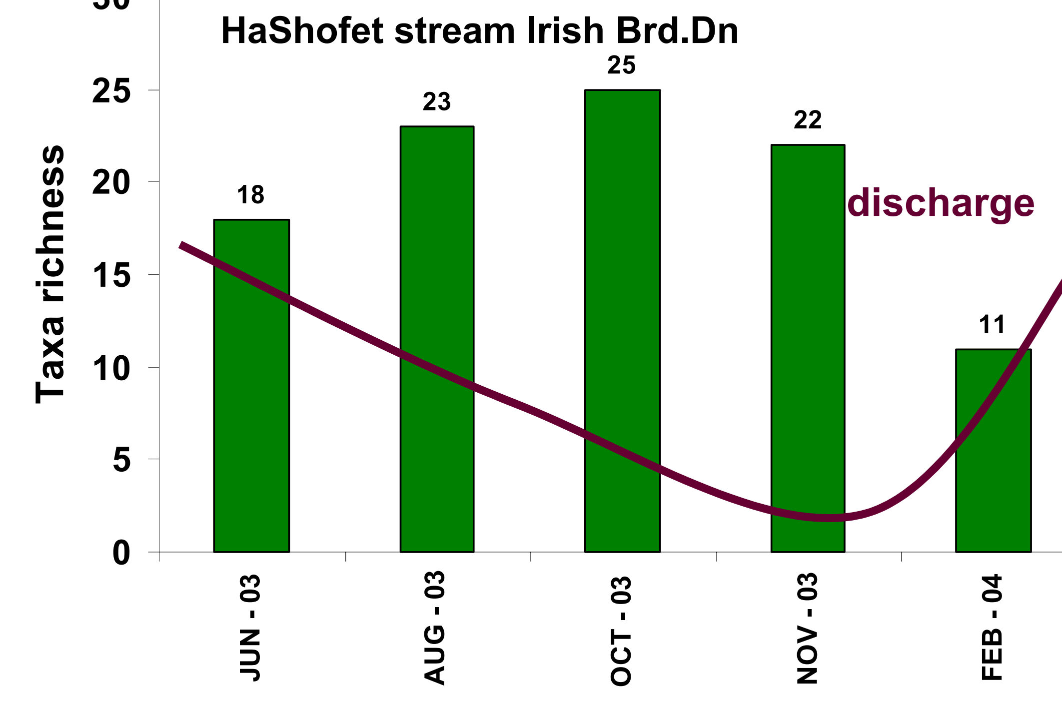

Proposed relationship between flow intensity, and ecosystem controls and community response



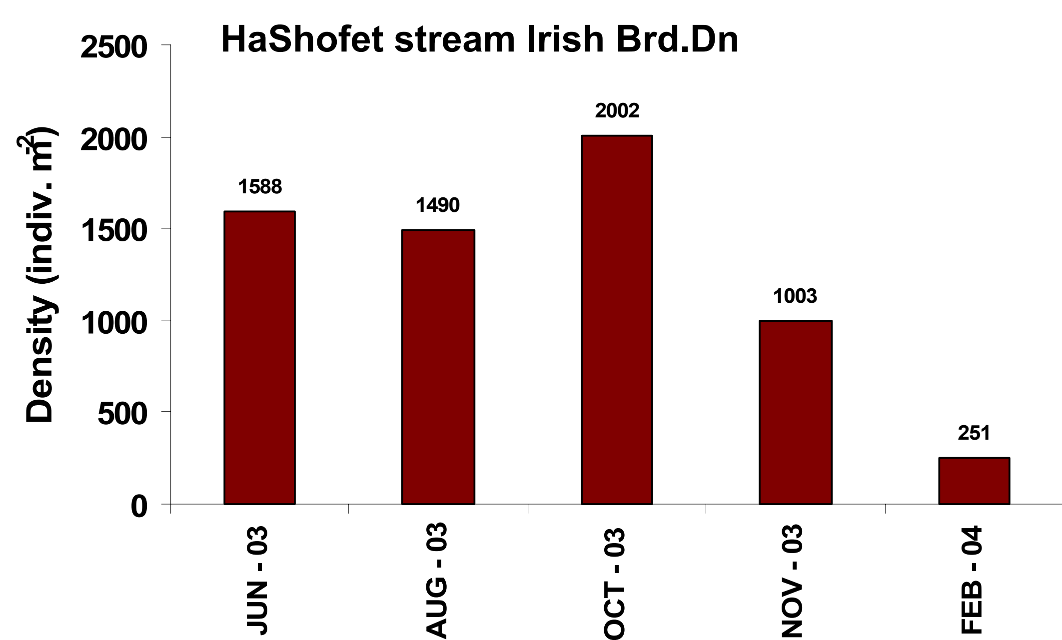
FLOW:	scouring	moderate	reduced
CONTROLS:	environmental	biological	environ. + biological
COMMUN. RICHNESS:	reduced	recovering	declining

Gasith & Hershkovitz,
TEL AVIV UNIVER

Effect of flood on macroinvertebrates richness



Effect of flood on macroinvertebrates density



Hershkovitz and Gasith, unpublished

Gasith & Hershkovitz, 2006
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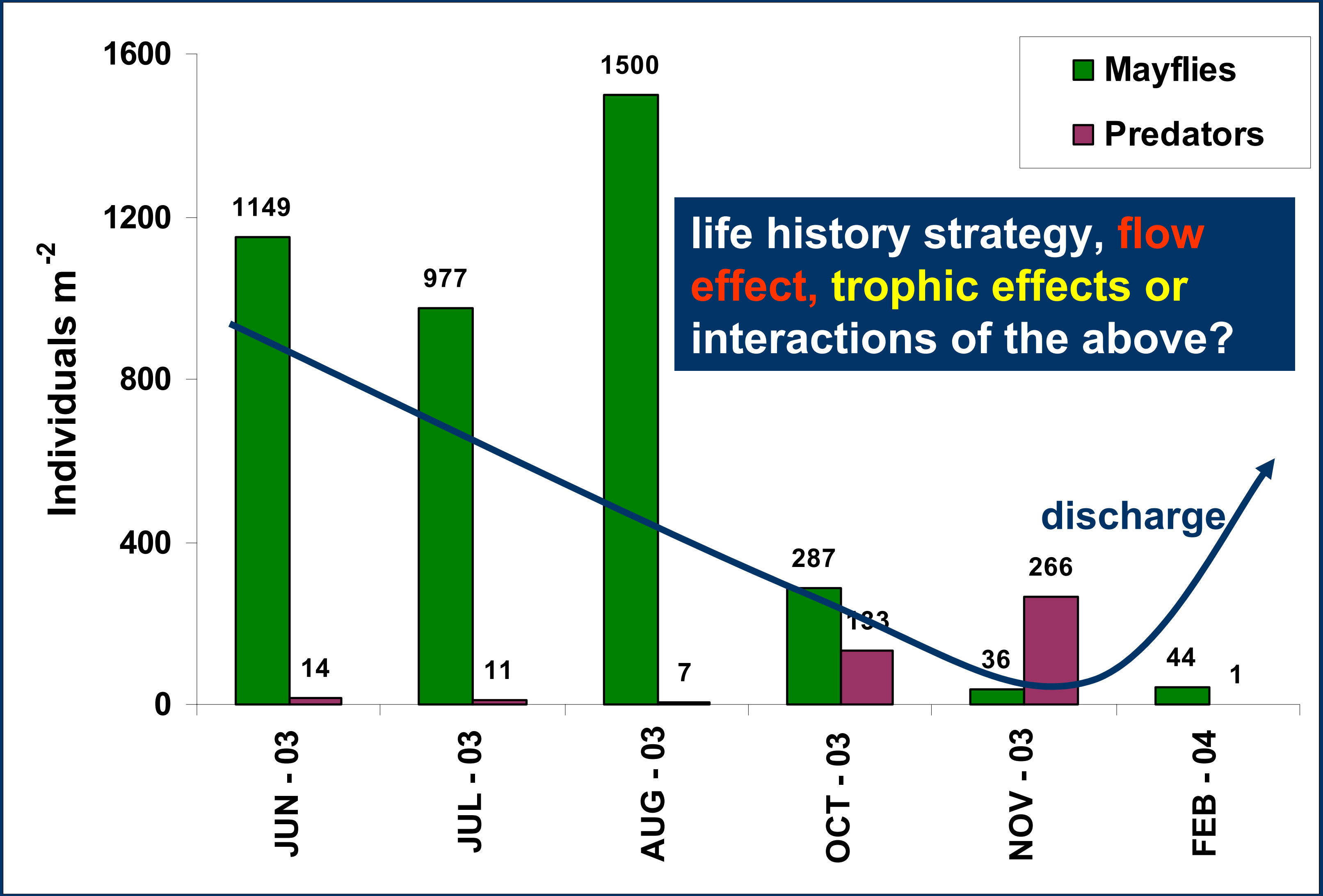
Seasonal changes in density of mayflies and predators

(Ha’Shofet stream, Irish Brd. Dn; Israel)



flash floods and life-history evolution

The case of mayflies agrees with the hypothesis that "…….. to balance tradeoffs between juvenile growth and mortality risk from floods most individuals should emerge before the pick of the flood season" (Lytle, 2002)

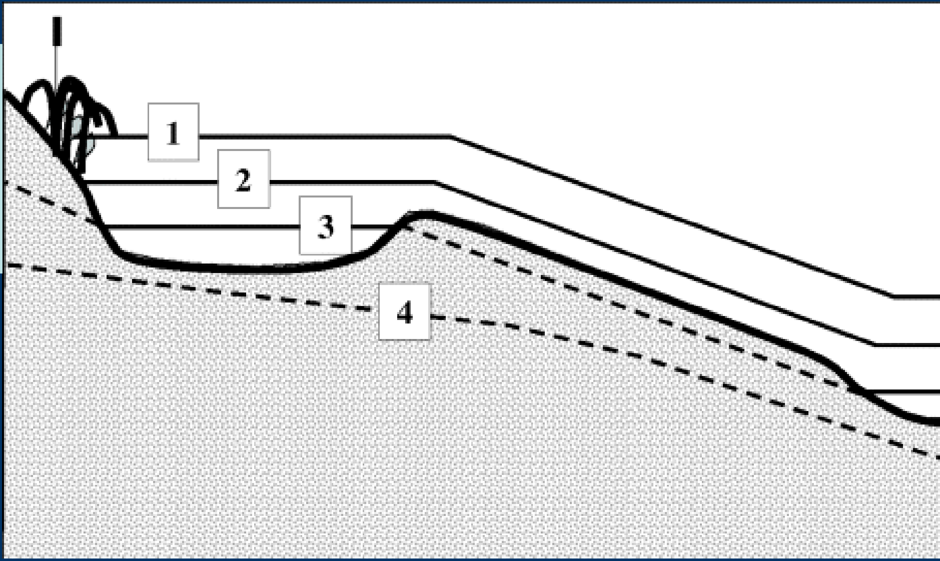
Community response to drying in MTS

Macroinvertebrates richness

Effects of drying

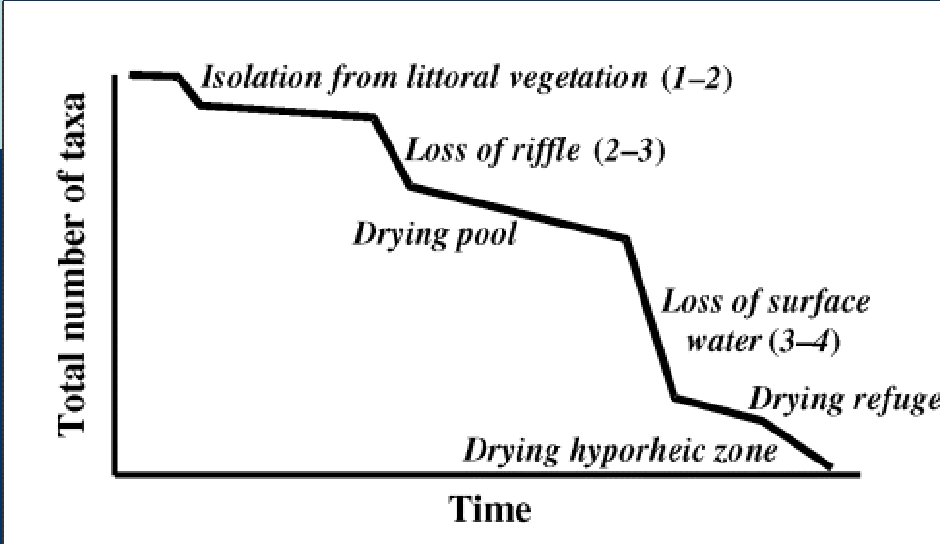
Loss of hydrologic connectivity change in habitat availability

(Resh and Gasith, 1999; Boulton, 2003)



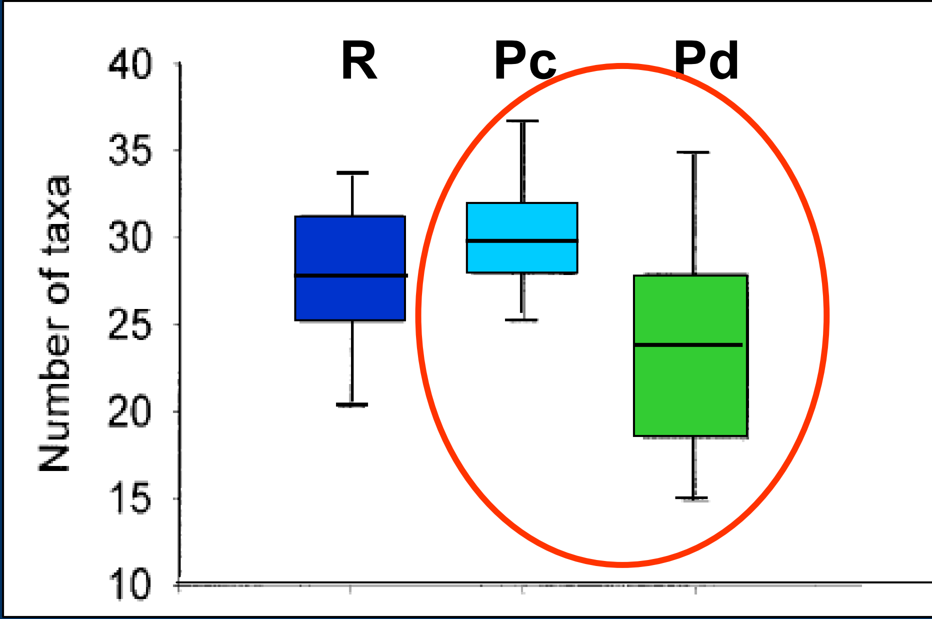
effects on taxa richness

(Boulton, 2003)



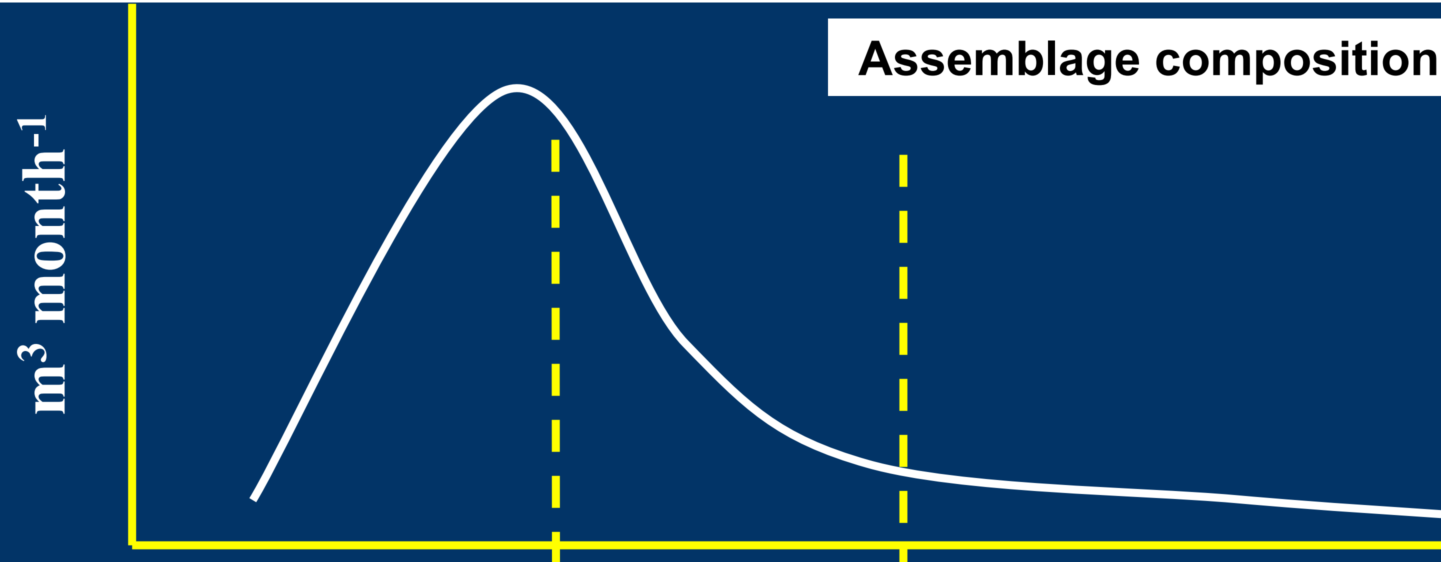
Benthic macroinvertebrate assemblages and microhabitat connectivity in mediterranean-type streams of northern California (Bonada et al., 2006)

significant drop in richness was evident only between connected (Pc) and isolated (Pd) pools



Proposed relationship between flow intensity, and ecosystem controls and community response

Assemblage composition



FLOW:	**scouring**	**moderate**	**reduced**
CONTROLS:	**environmental**	**biological**	**environ. + biological**
COMMUN. RICHNESS:	**reduced**	**recovering**	**declining**
ASSEMBLAGE COMPOSITION:	**winter**	**spring-summer**	**summer – fall /fall**

Gasith & Hershkovitz, 2006
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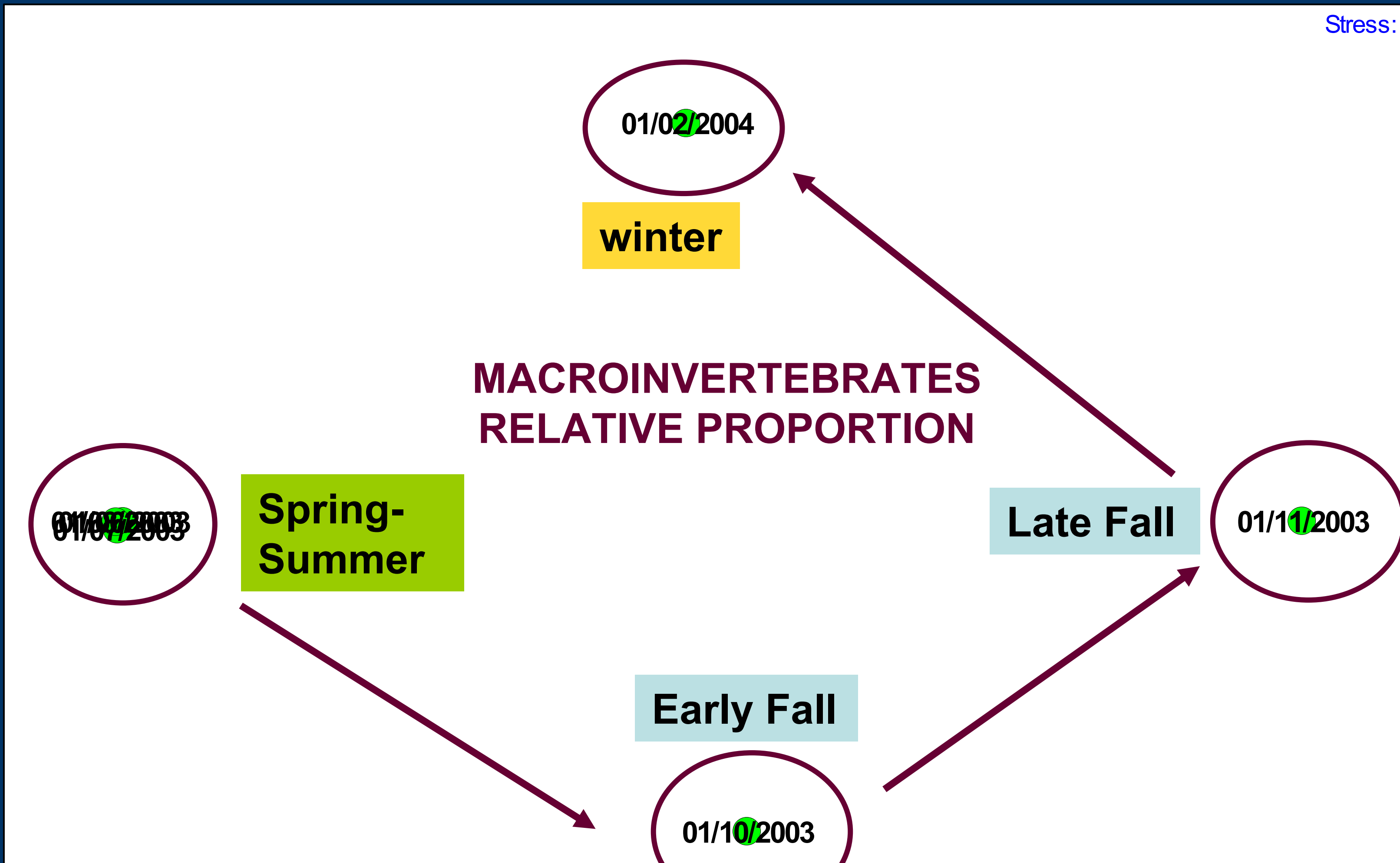
Seasonal segregation of macroinvertebrate assemblages

Multi-Dimensional Scaling - similarity analysis



Ha'Shofet stream Irish Brd. Dn 2003/4
Hershkovitz & Gasith, unpublished

Gasith & Hershkovitz, 2006
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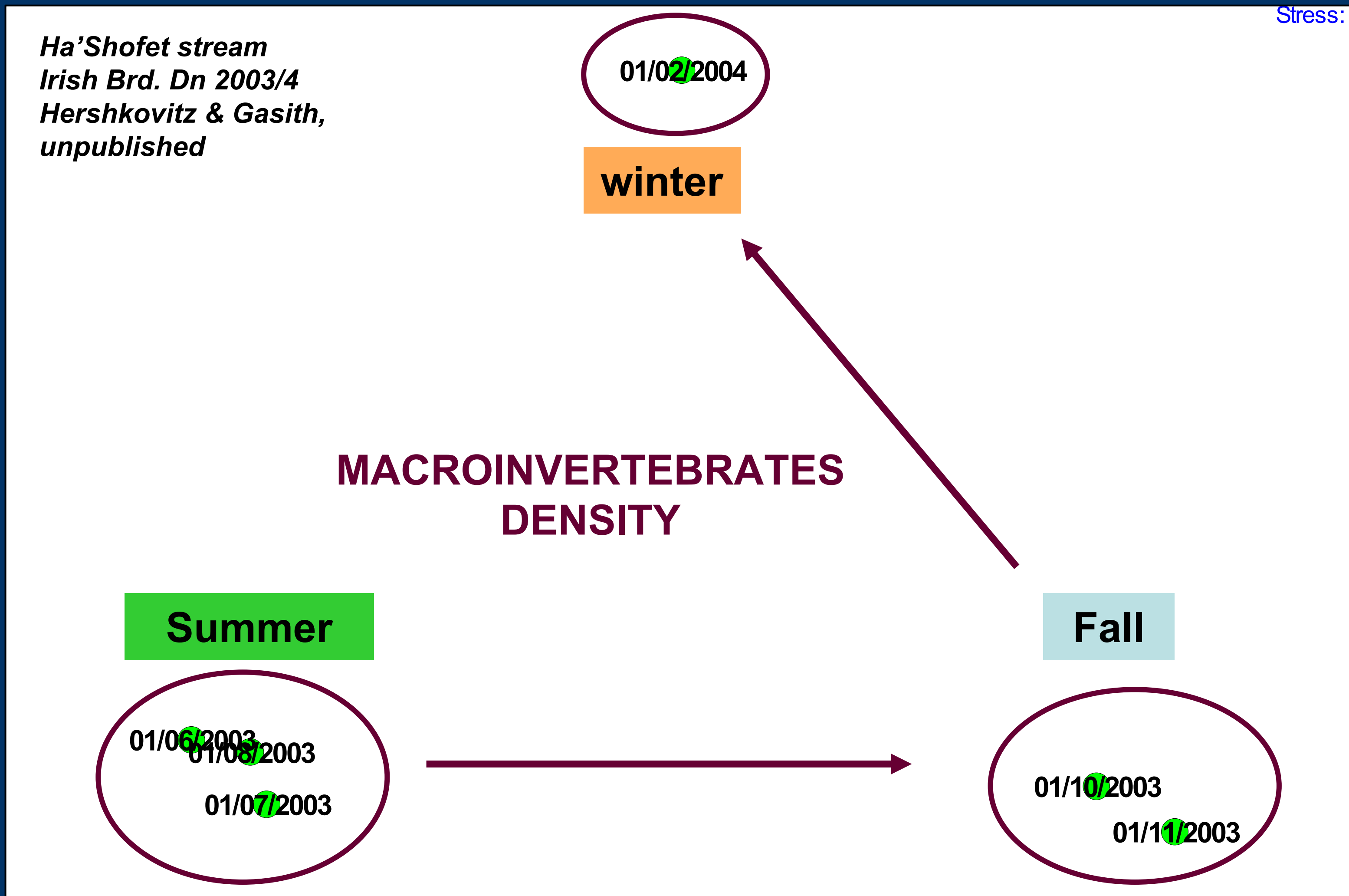
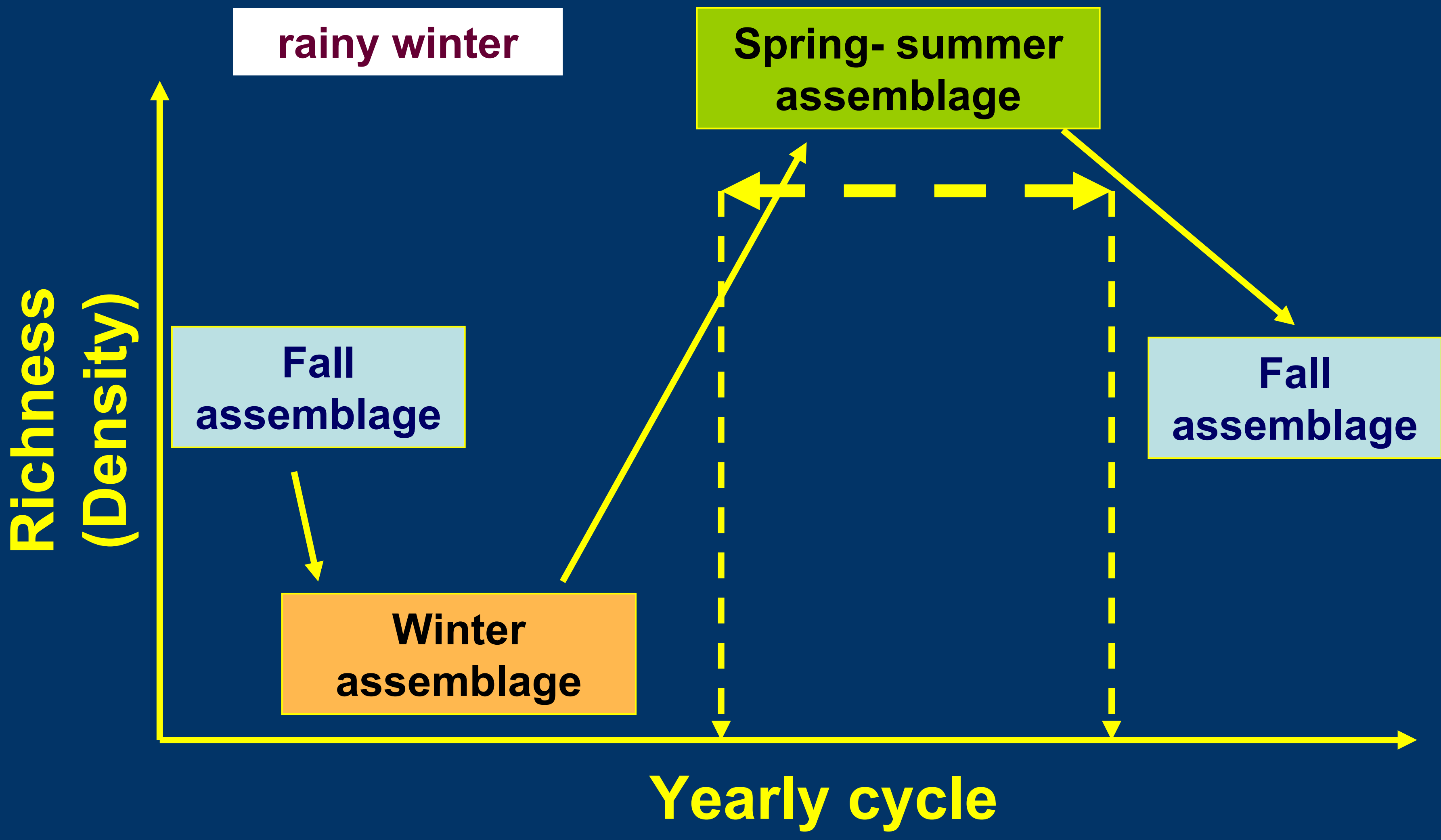
Seasonal segregation of macroinvertebrate assemblages

Multi-Dimensional Scaling - similarity analysis



Expected temporal change in MTS macroinvertebrate assemblages and its duration



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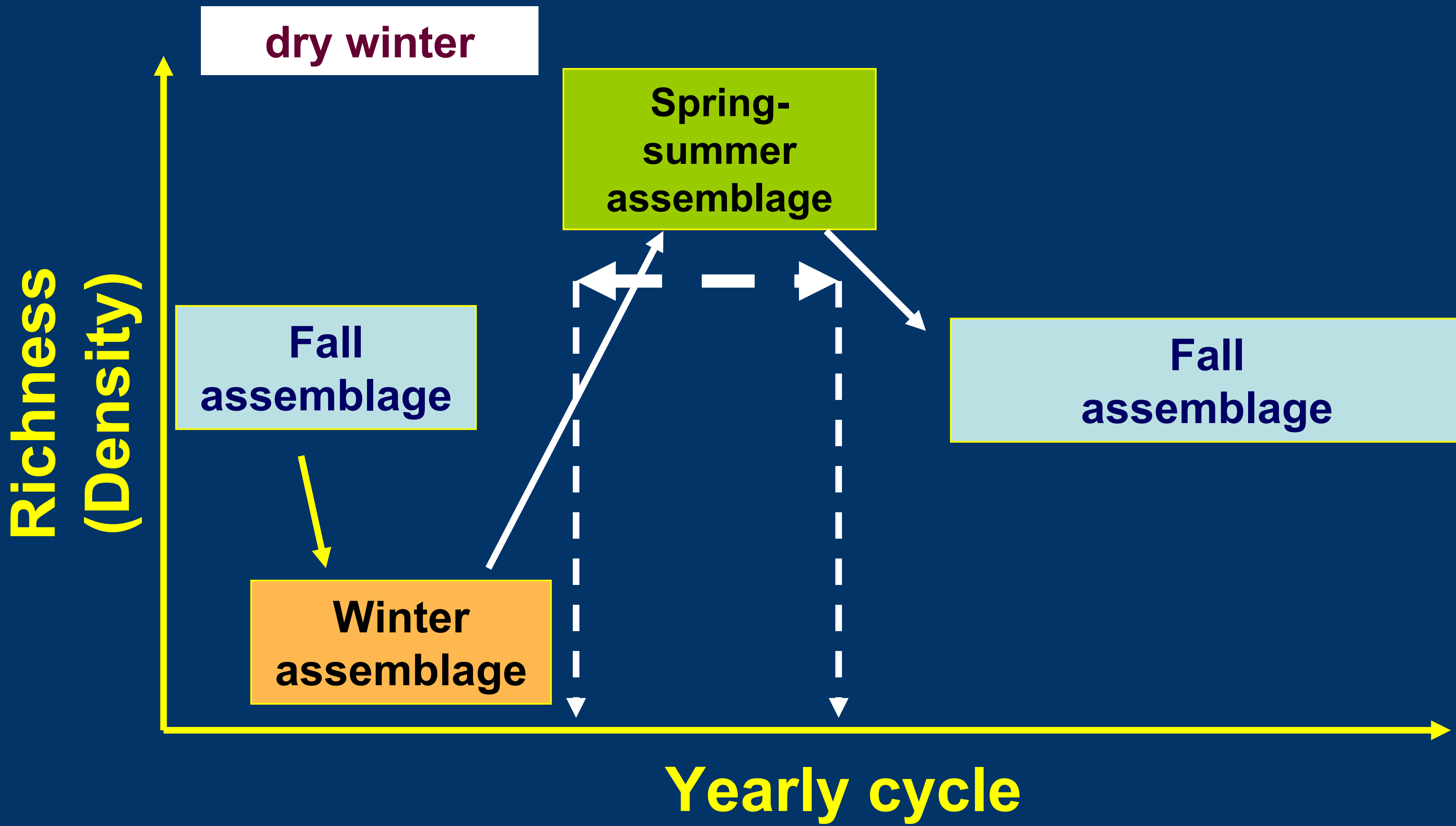

MTS hydrology and life-history evolution (species trait)

Adaptation to MTS hydrology is expected to select for life-history traits that favor avoidance or resistance from being washed away by floods, and for survival during a period of reduced flow
(Gasith and Resh, 1999)

An example for a fish life cycle attuned with MTS hydrology

Gasith & Hershkovitz, 2006
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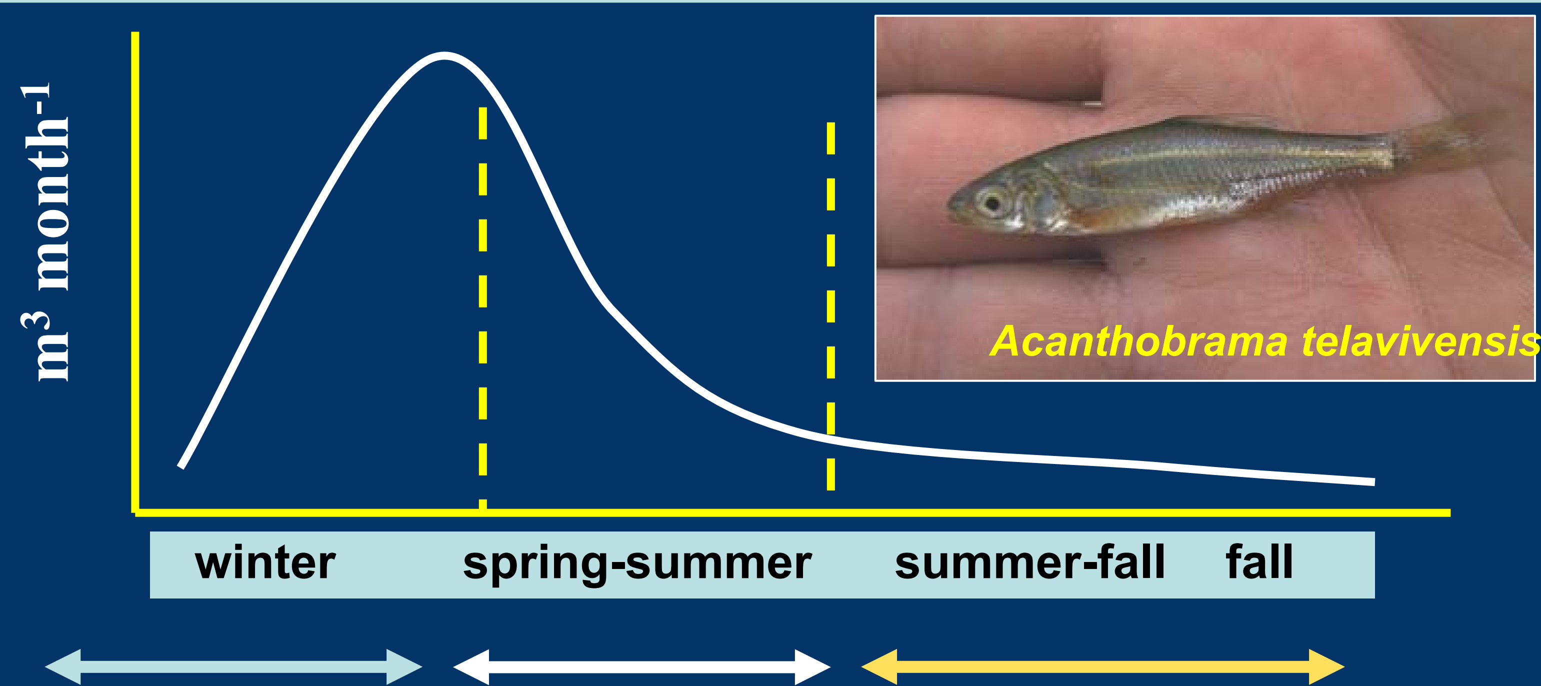
Reproductive strategy of a small endemic cyprinid, the Yarqon bleak (Acanthobrama telavivensis), in a mediterranean-type stream

Eldad Elron, Avital Gasith and Menachem Goren (Environ. Biol. Fish 2006)



risk of exposure of early stages to scouring flows	**expectation:** best period for breeding	risk of exposure of early stages and juveniles to drought conditions

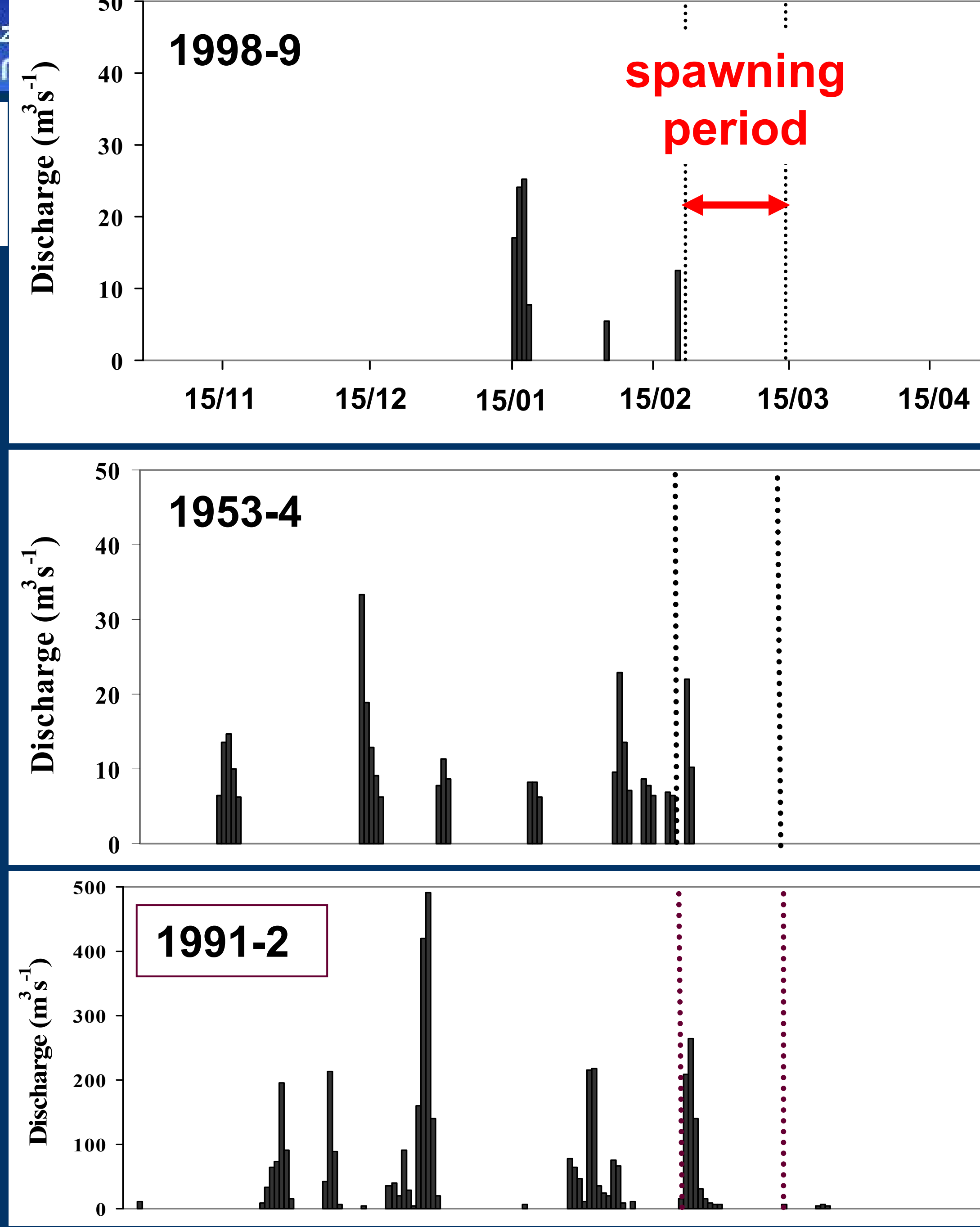
Gasith & Hershkovitz
TEL AVIV UNIVE

Timing and peak of daily discharge (> $5 m^3 s^{-1}$)

drought year

average year

rainy year



Flood cessation transitional period recruitment model (Elron et. Al., 2006)

Breeding at the transitional period between high and low flows in MTS puts early stages somewhat at risk of being washed away by late floods, but gains them a longer period of growth under favorable conditions (Elron et al., 2006)

agrees with finding by others : Herrera & Fernandez-Delgado, 1994, Fernandez-Delgado & Herrera, 1995; Ribeiro et al., 2000; Marchenti & Moyle, 2000; Magalhaes et al., 2003

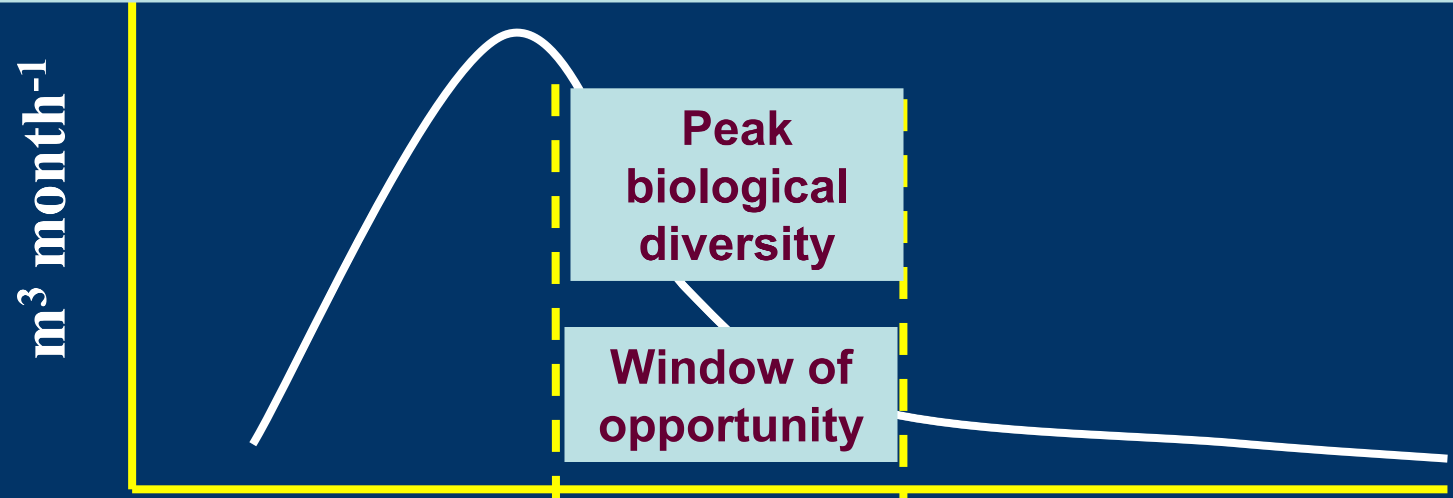
Conclusion I

mediterranean-type streams

are fluvial systems that are physically, chemically and biologically shaped by sequential, seasonal predictable events of contrasting flows, that vary markedly in intensity on a multi-annual scale and within the mediterranean-climate range

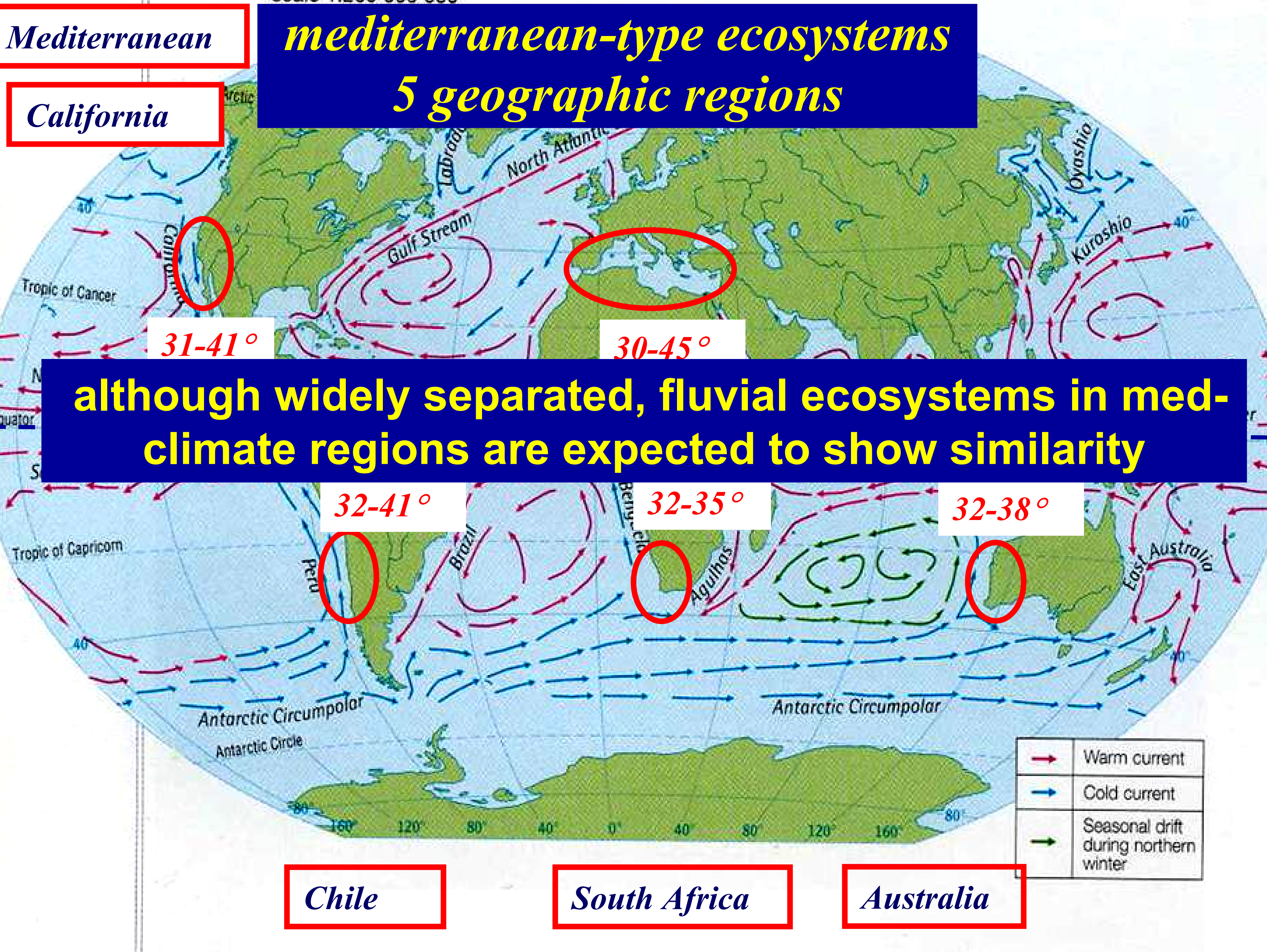
they are ecosystems under deterministic and stochastic regulation

Conclusion II



FLOW:	scouring	moderate	reduced
CONTROLS:	environmental	biological	environ. + biological
COMMUN. RICHNESS:	reduced	recovering	declining
ASSEMBLAGE COMPOSITION:	winter	spring-summer	summer - fall

mediterranean-type ecosystems
5 geographic regions



although widely separated, fluvial ecosystems in med-climate regions are expected to show similarity

Ecology of macroinvertebrate community in mediterranean rivers at different scales and organization levels

Nuria Bonada 2003

under the supervision of: Narcis Prat & Maria Rieradevall

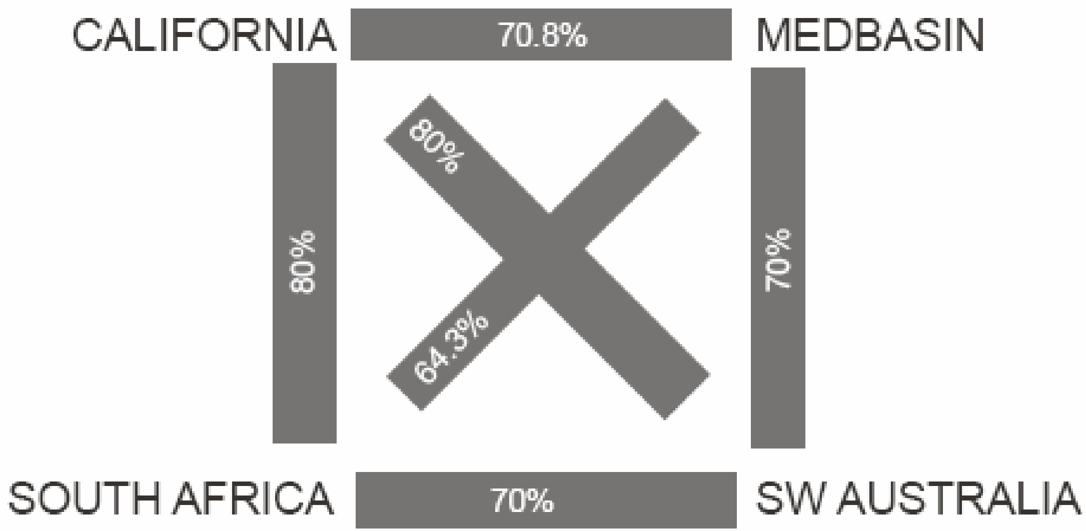


Figure 12. Percentages of similarity between med-regions considering common abundant (IV value) and representative taxa in riffle and pool habitats

Restoration of MTS

ecological perspective

Restoration = ecosystem repair

eliminating or minimizing man-made effects

The R-R-R approach

Gasith & Hershkovitz, 2006
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Level of restoration

Gasith & Hershkovitz, 2006
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Level of restoration

restore to the original state

maximum <u>possible</u> repair of ecosystem structure and function and its capacity for long-term self regulation

mostly aesthetic repair

Repair level

Effort and time

Alteration

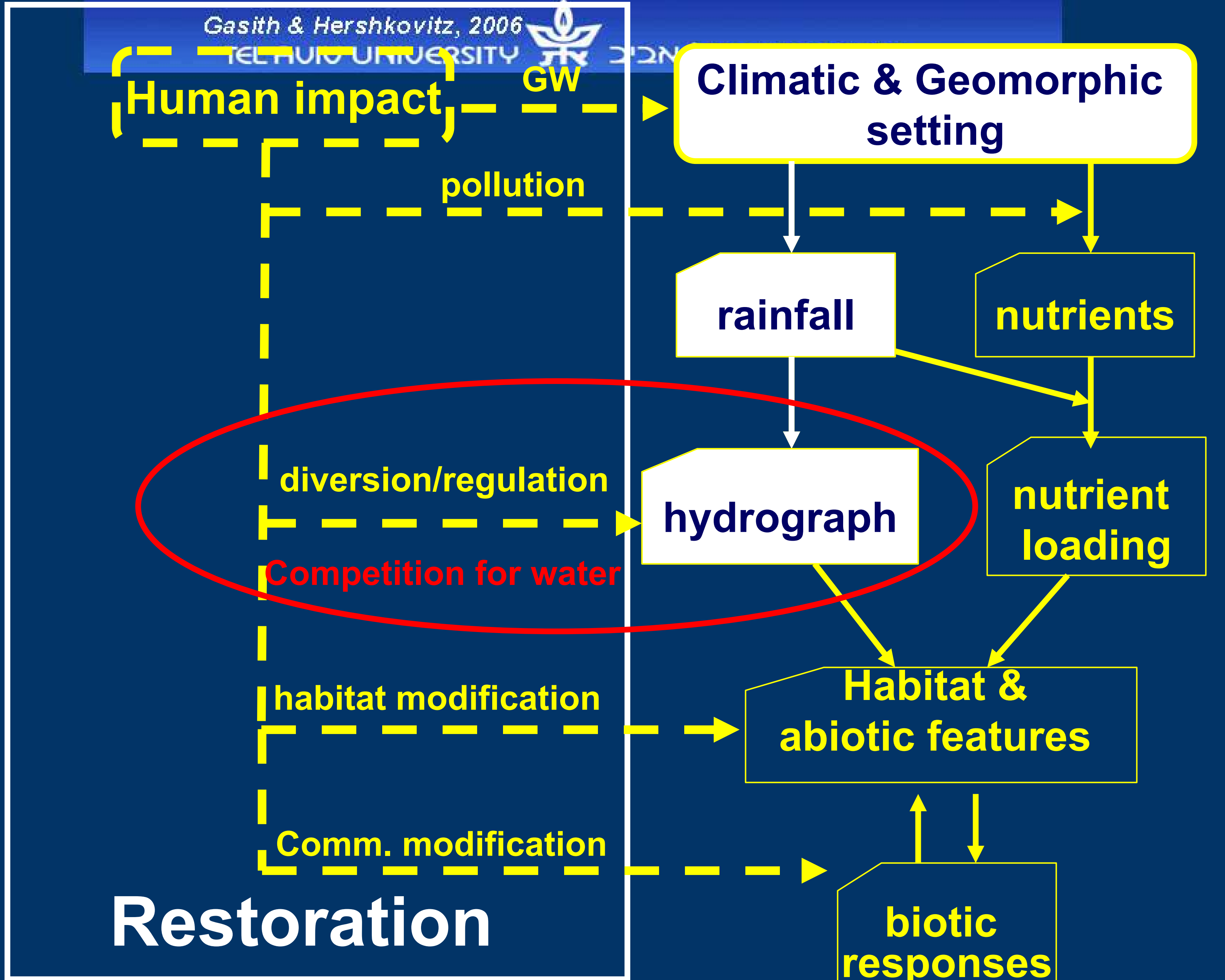
Transformation

greening the desert by turning an ephemeral stream into a perennial one, is not restoration

Transformation

Einot Huga, Israel (Gasith)

"dull looking", natural habitat → **"restored"** → **attractive water body**


Gasith & Hershkovitz, 2006
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Human impact
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Climatic & Geomorphic setting
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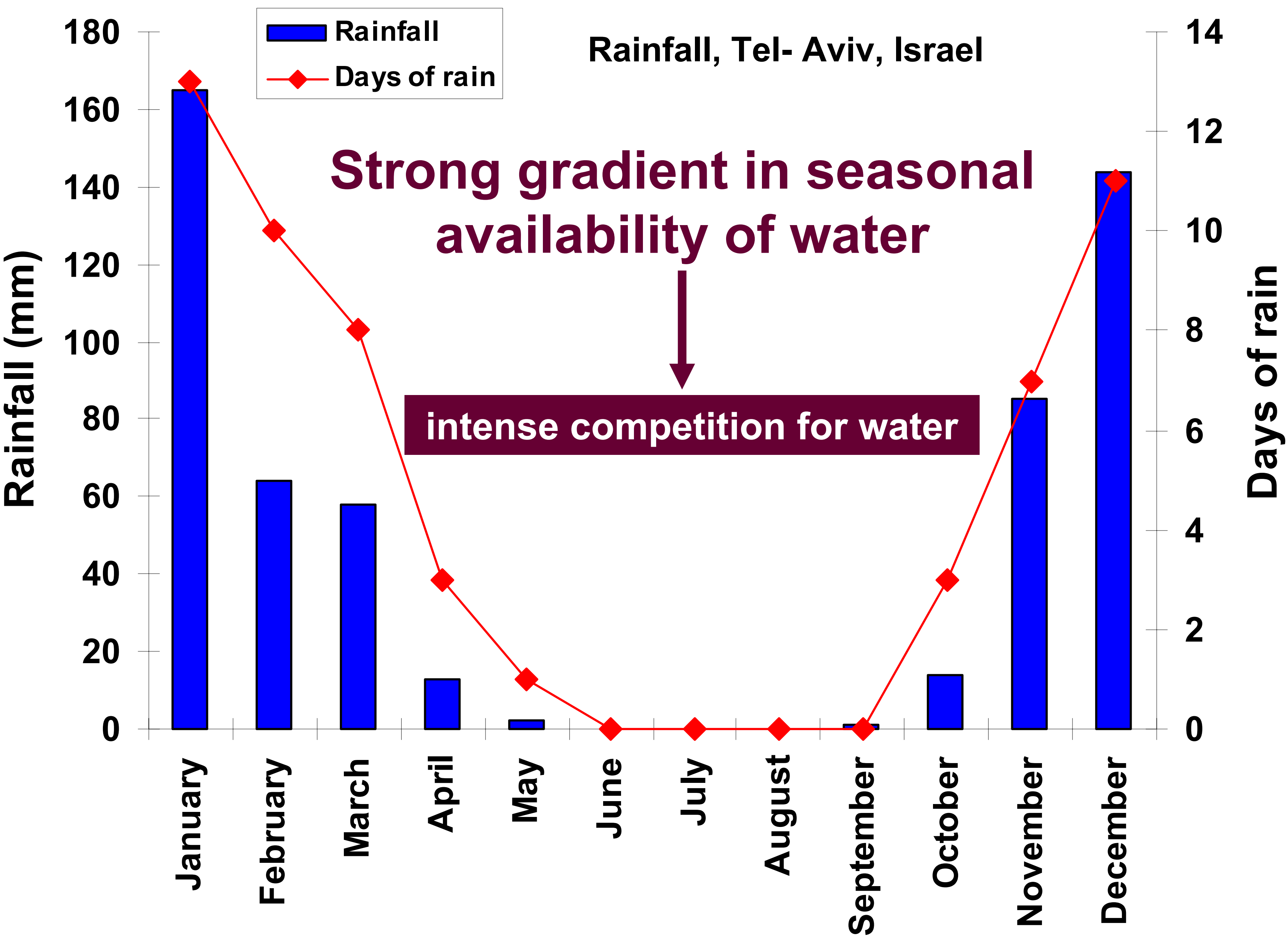
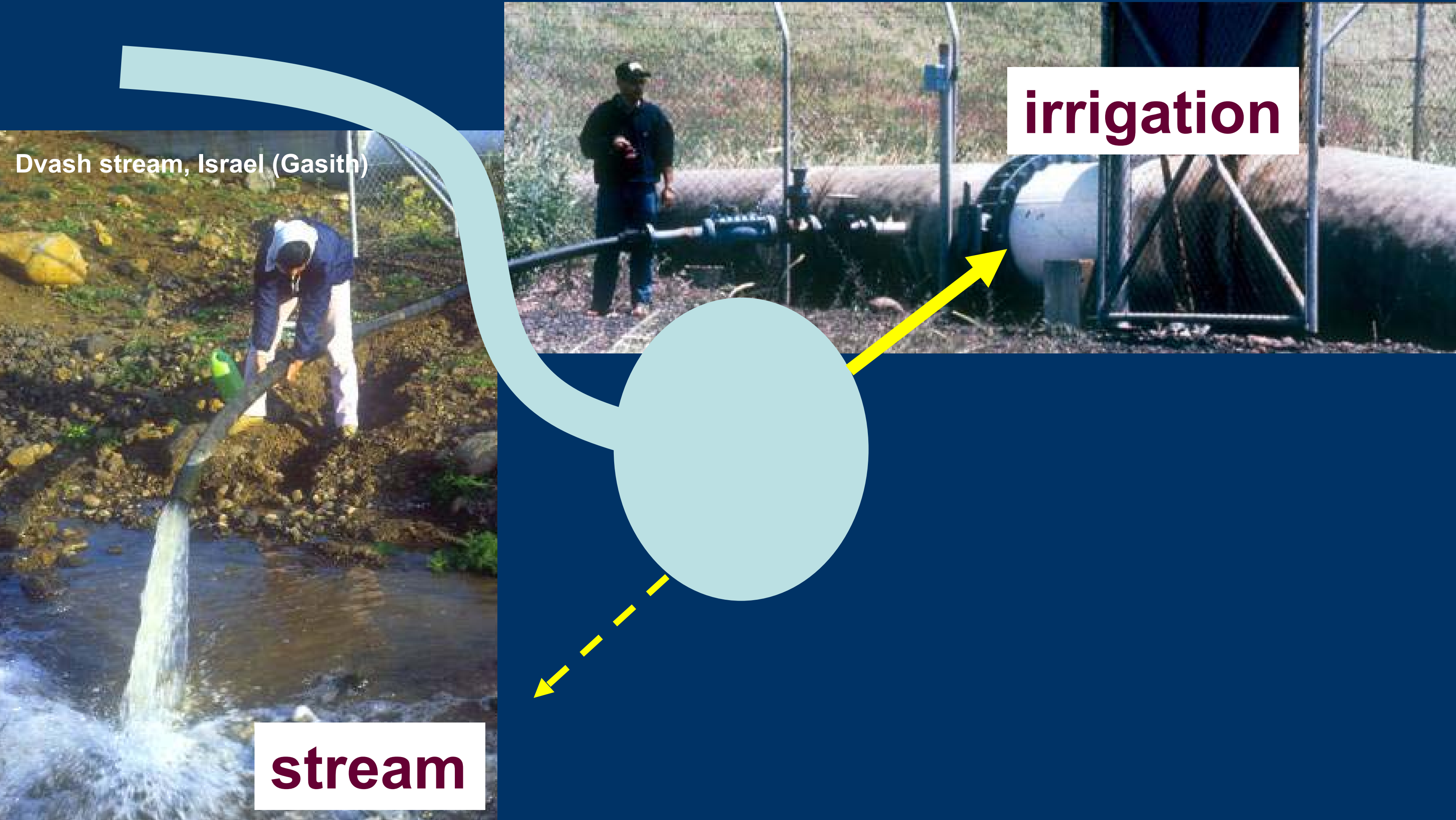
Competition for water
habitat modification
Habitat & abiotic features
Comm. modification
biotic responses
Restoration


Rainfall, Tel- Aviv, Israel
Rainfall
Days of rain
Strong gradient in seasonal availability of water
intense competition for water
Rainfall (mm)
Days of rain
180
160
140
120
100
80
60
40
20
0
14
12
10
8
6
4
2
0
January
February
March
April
May
June
July
August
September
October
November
December

Gasith & Hershkovitz, 2006
TEL AVIV UNIVERSITY אוניברסיטת תל-אביב

Aquatic ecosystem pay a heavy toll due to intense competition for water



Gasith & Hershkovitz, 2006
TEL AVIV UNIVERSITY

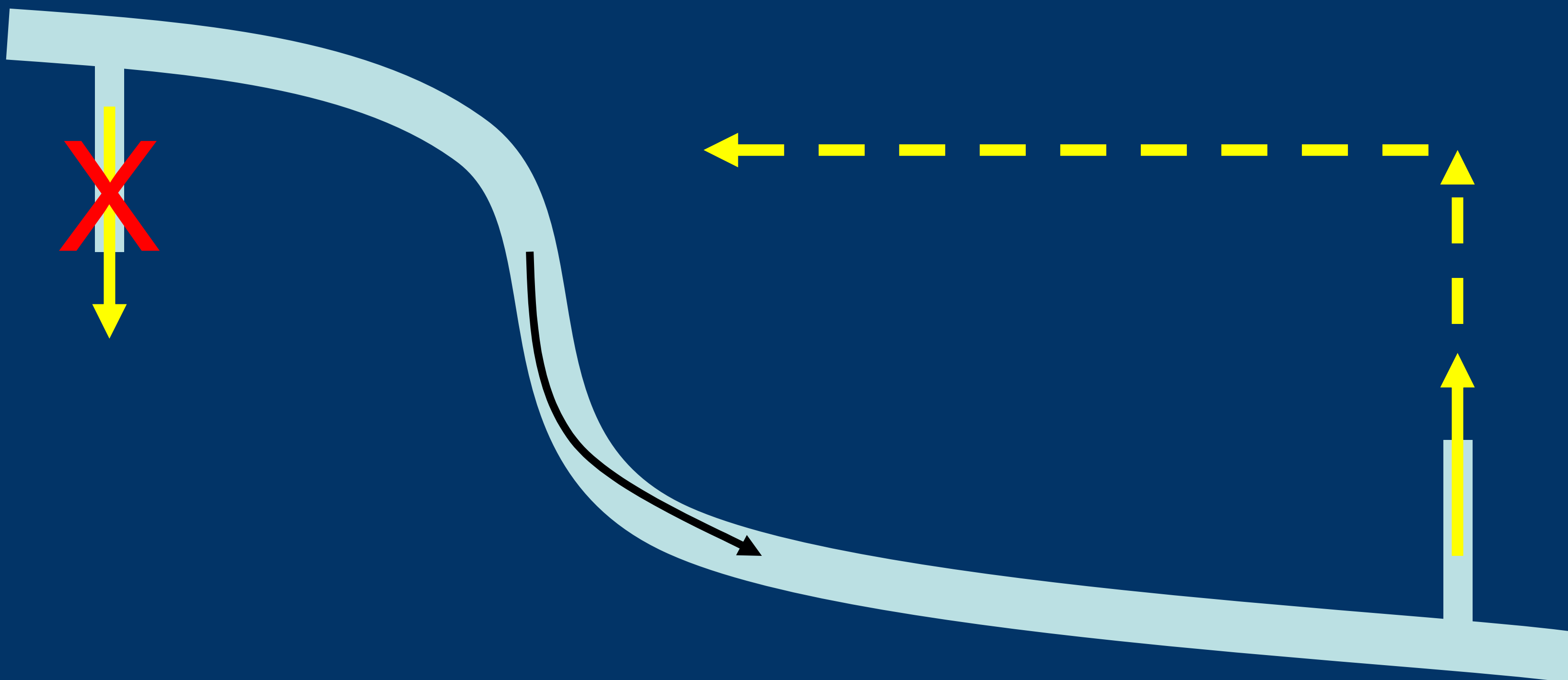
Yarqon River, Israel

Today – hardly flowing, polluted stream

Until 1950 – unpolluted, perennial river, second only to the Jordan River!

The unique features of MTS call for special consideration of restoration needs

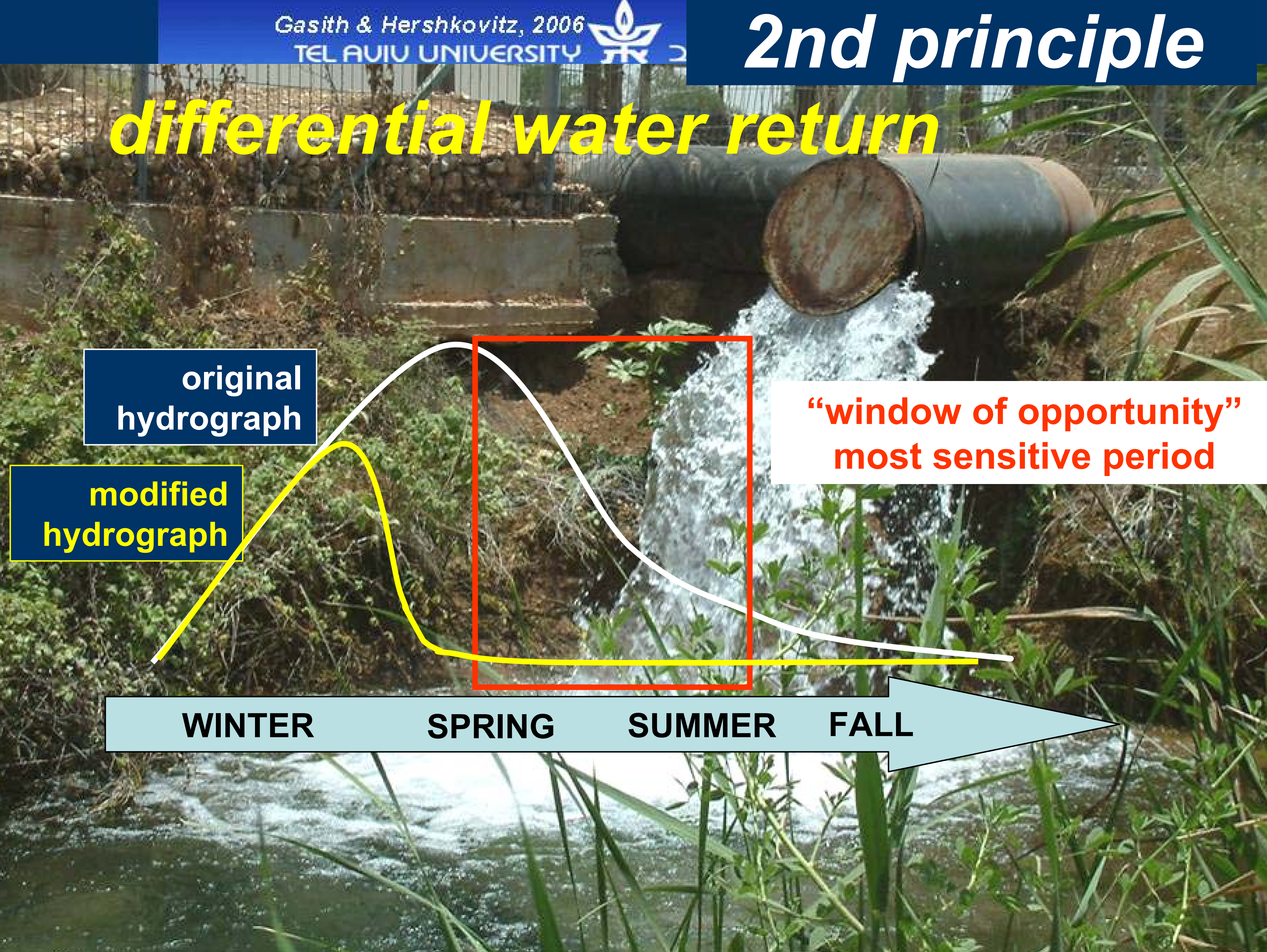
1st principle: “have the water and drink it too”



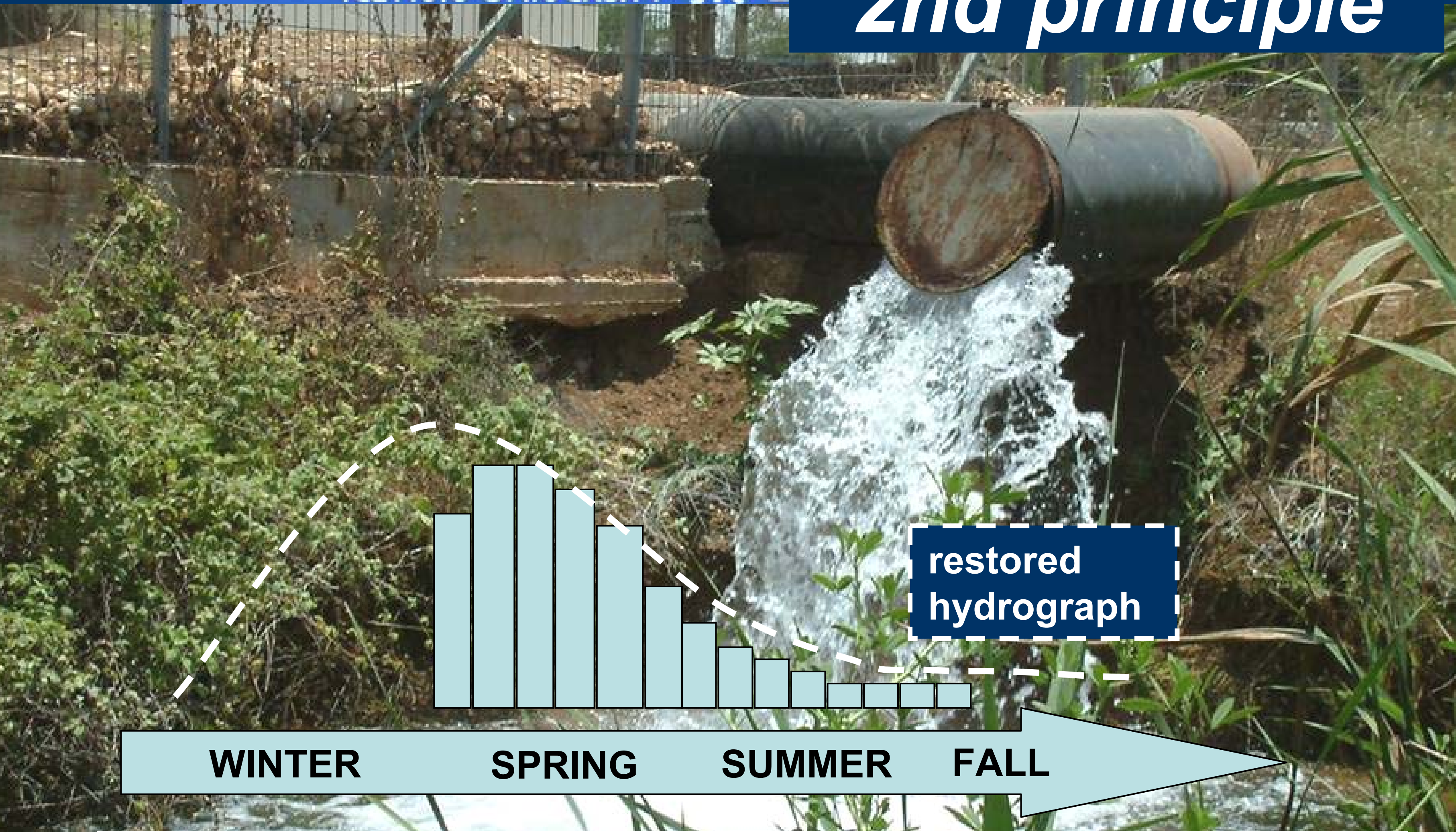
maximize ecosystem services by limiting water diversion to “downstream”

1st principle:
"have the water and drink it too"

maximize ecosystem services by limiting water diversion to "downstream"

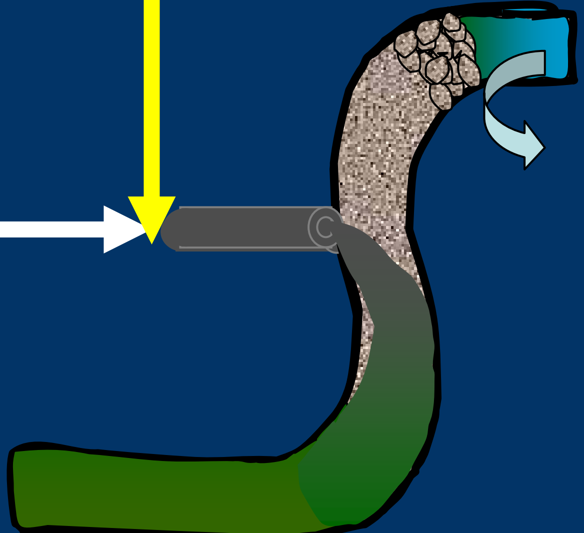

Gasith & Hershkovitz, 2006
TEL AVIV UNIVERSITY
2nd principle
differential water return
original hydrograph
modified hydrograph
"window of opportunity" most sensitive period
WINTER
SPRING
SUMMER
FALL

2nd principle



restore MTS hydrologic pattern by differential return of allocated water

Reclaimed wastewater used for stream restoration in regions of water scarcity is yet to be proved justified



Gasith et al., 1998; Prat and Munne, 2000

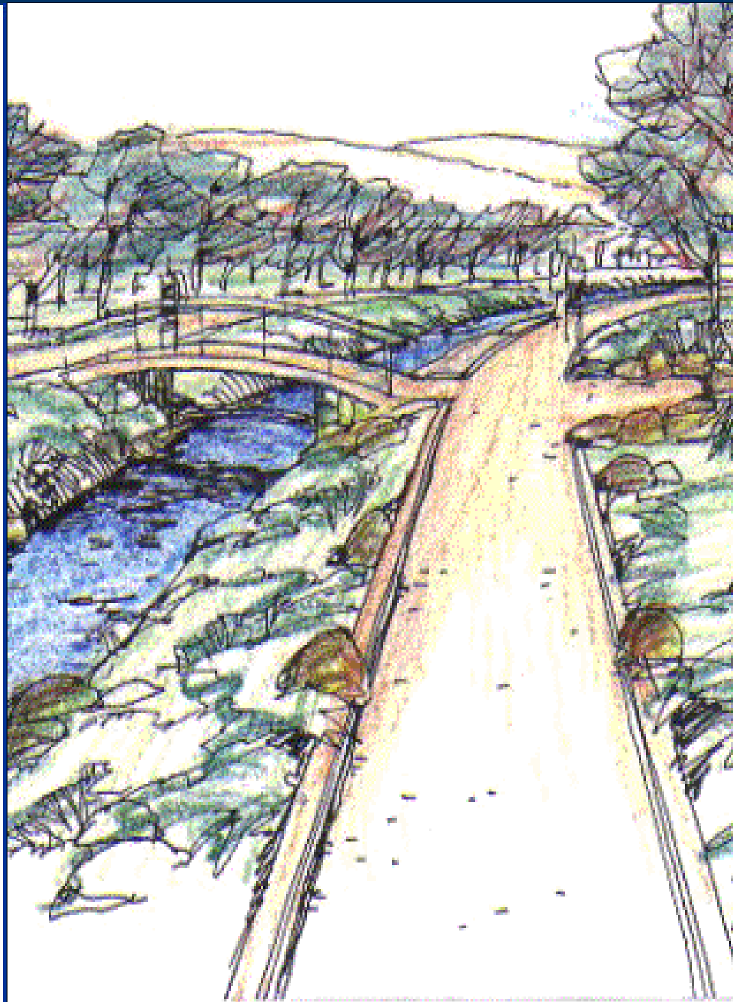
Israel's map of streams under rehabilitation project

(having or developing Master Plans)

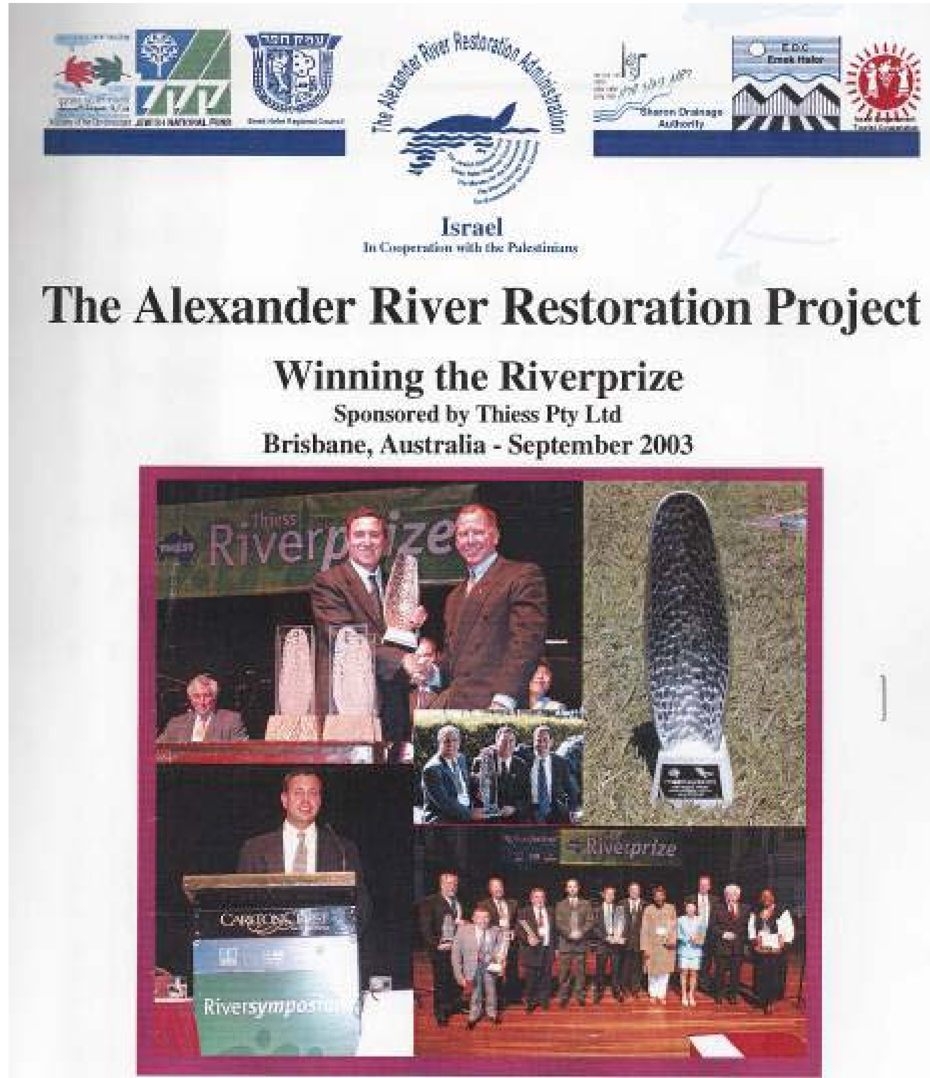
river authority
river boards
awaits planning

מרכז מידע גיאוגרפי
אשכול מדיניות ותכנון
המשרד לאיכות הסביבה

20 0 20 Kilometers



Alexander stream, Israel
(transbounday restoration)



Ibis (Plegadis facinellus), Alexander stream, Israel (Gasith)