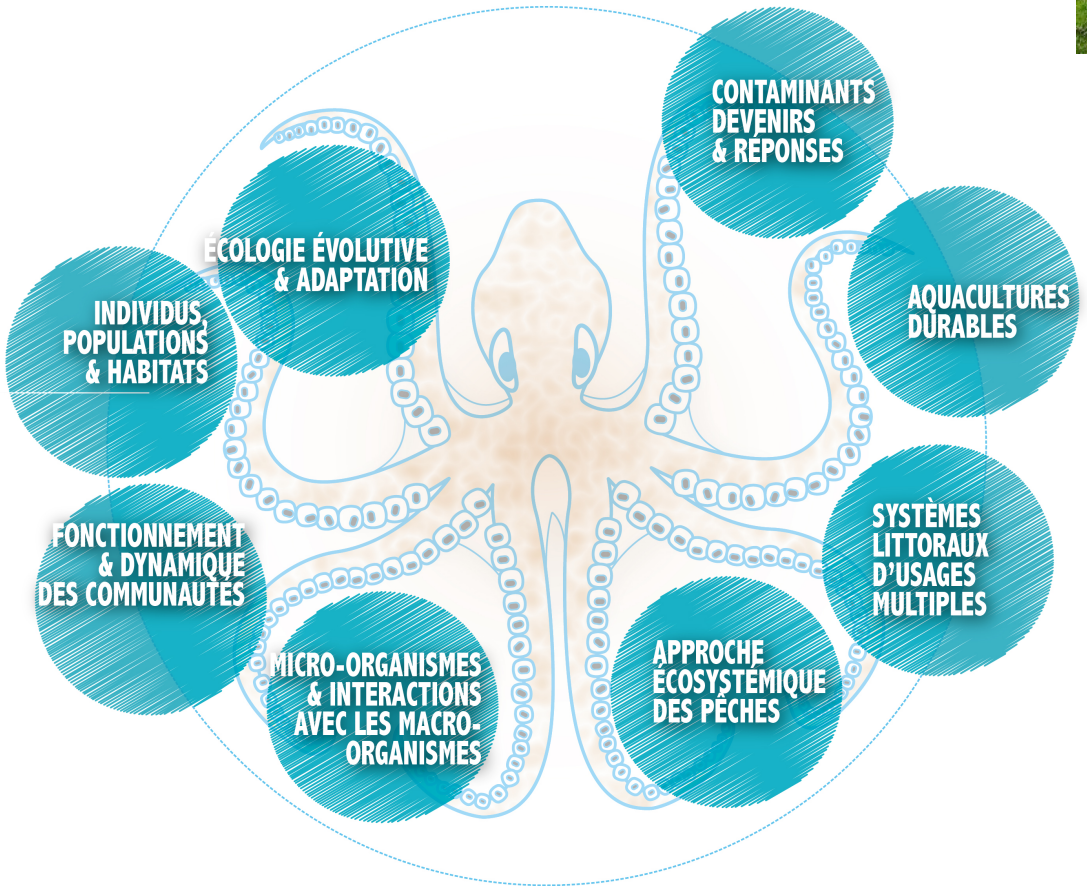
Mediterranean coastal lagoon ecosystems: ecological restoration and assessment of ecosystem services

Rutger de Wit

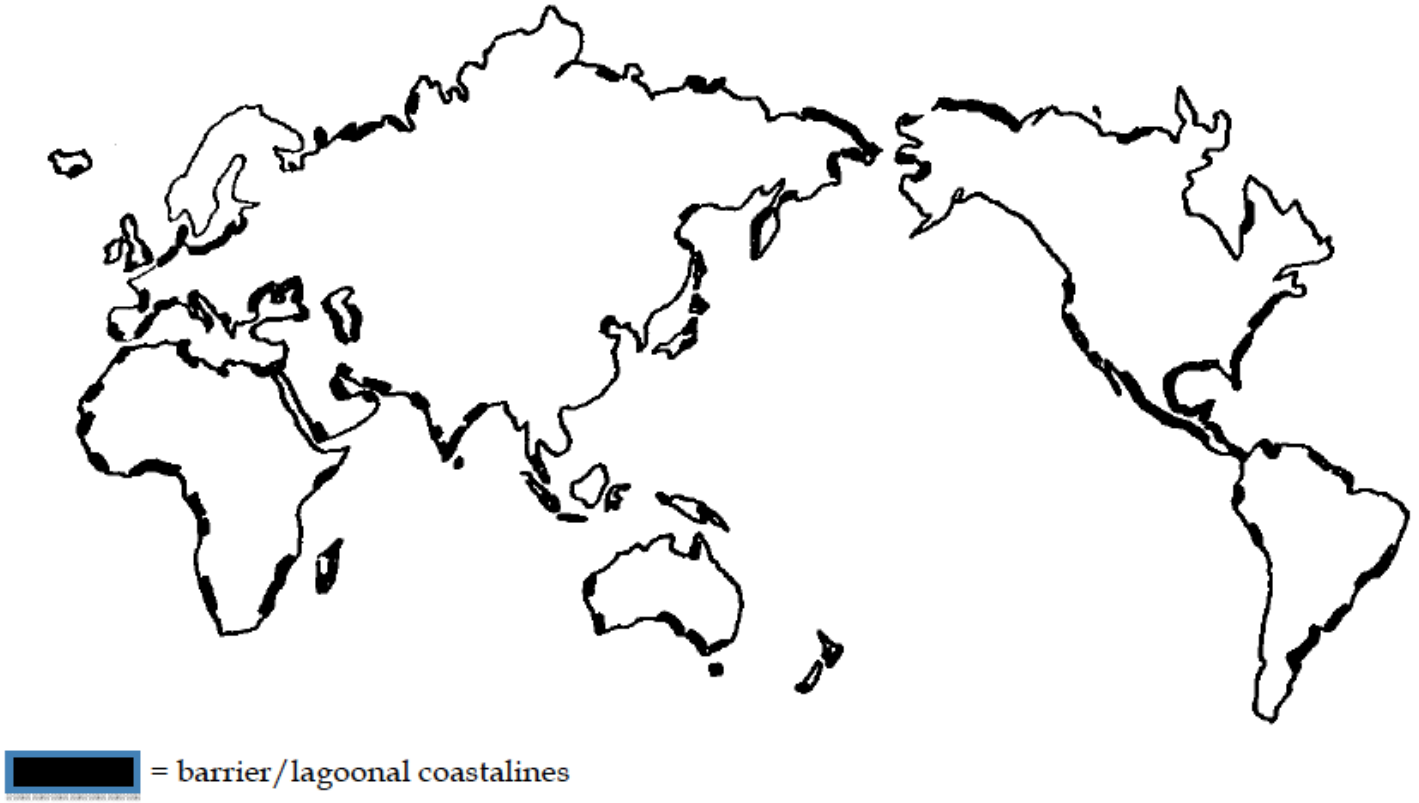
UMR MARBEC Centre for Marine Biodiversity Exploitation and Conservation

marbec
marine biodiversity
exploitation & conservation



Coastal lagoons

(30,000 referenced = 12 % of world coastlines)



= barrier/lagoonal coastalines

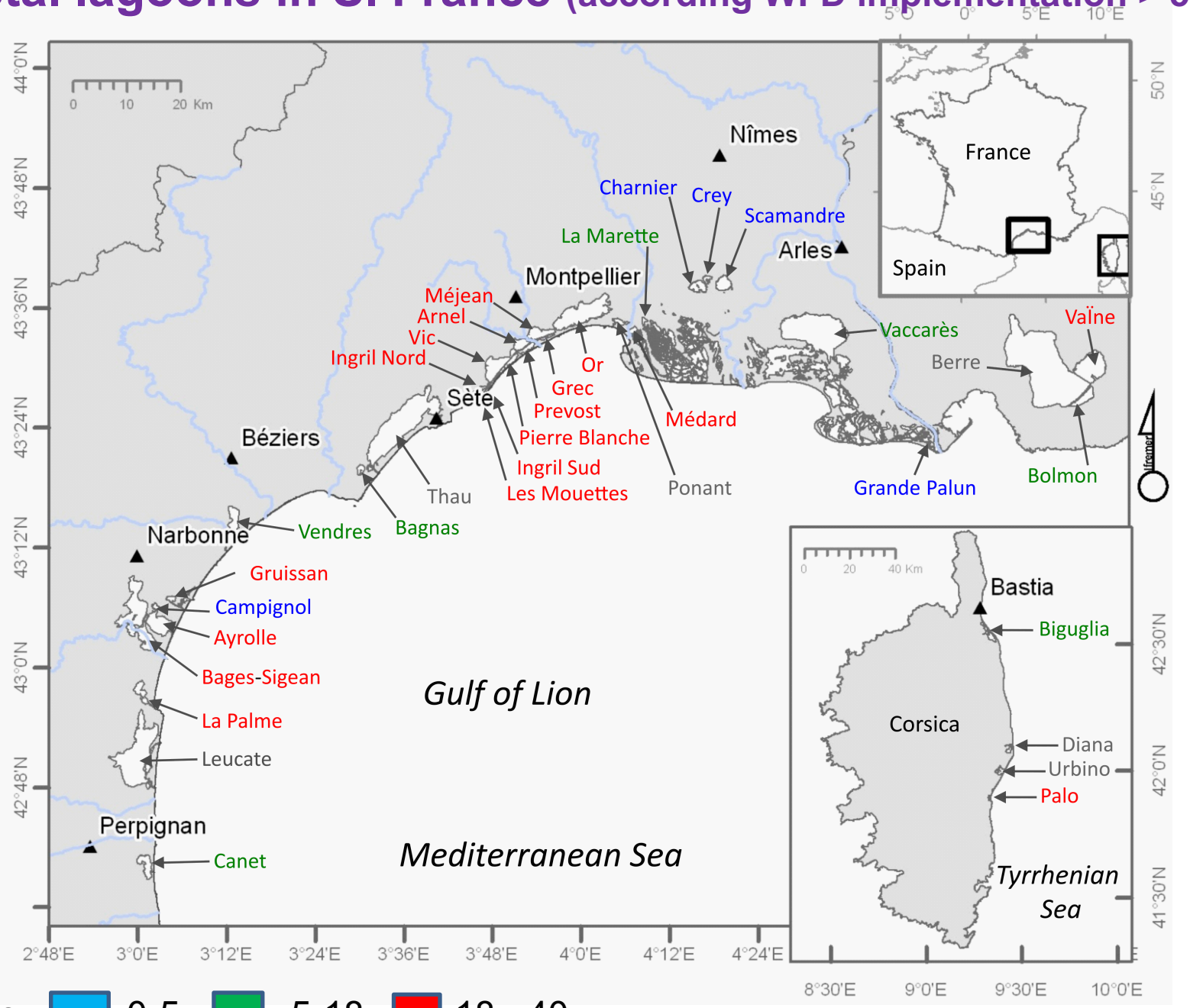
Fig. 1. World distribution of barrier and lagoonal coastlines. Reproduced from Barnes (1980), Coastal Lagoons, Fig. 1.1 on page 2, with kind permission of Cambridge University Press.

Coastal lagoons in the Mediterranean Sea

Transitional Water Data Platform - http://www.circlemednet.unisalento.it

> 600 coastal lagoons in the Mediterranean Sea

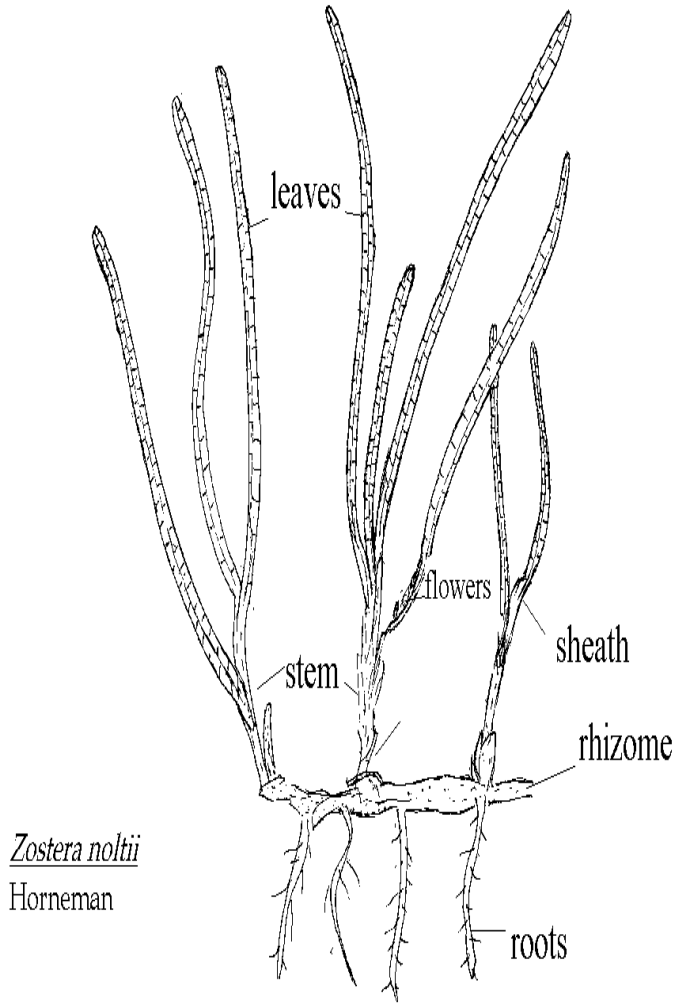
Coastal lagoons in S. France (according WFD implementation > 50 ha.)

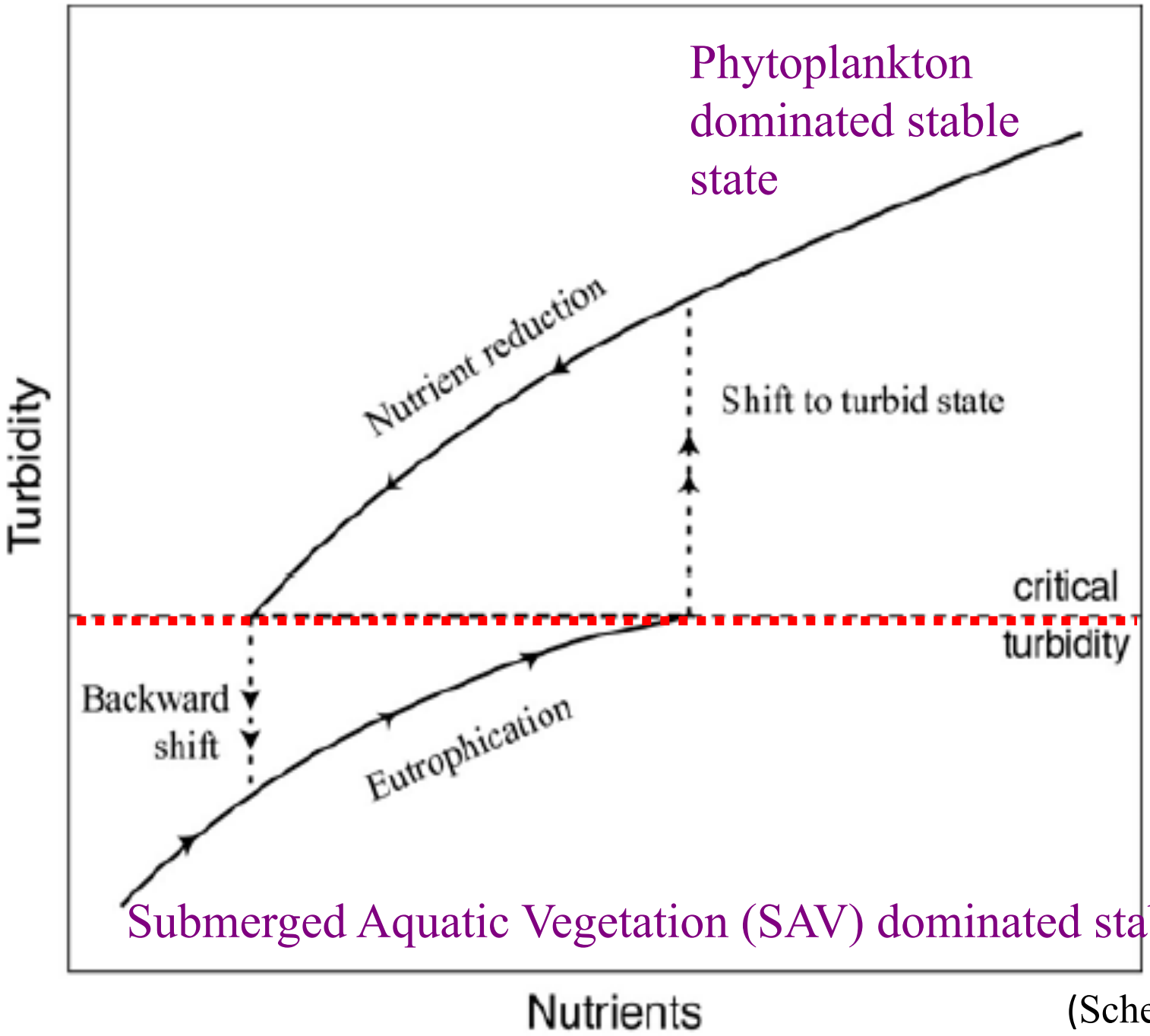


Salinities: 0-5, 5-18, 18 - 40

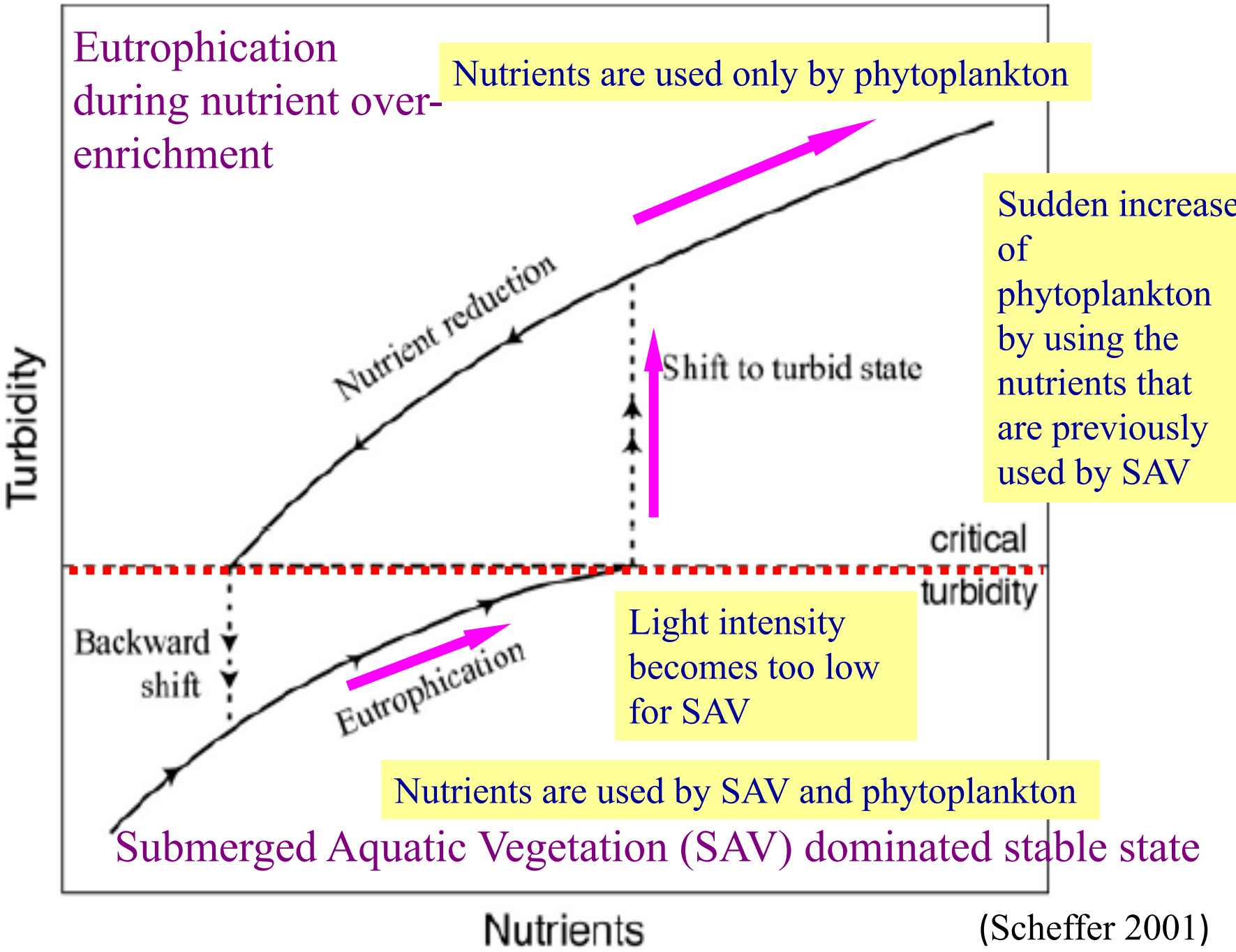
Courtesy Inès Le Fur

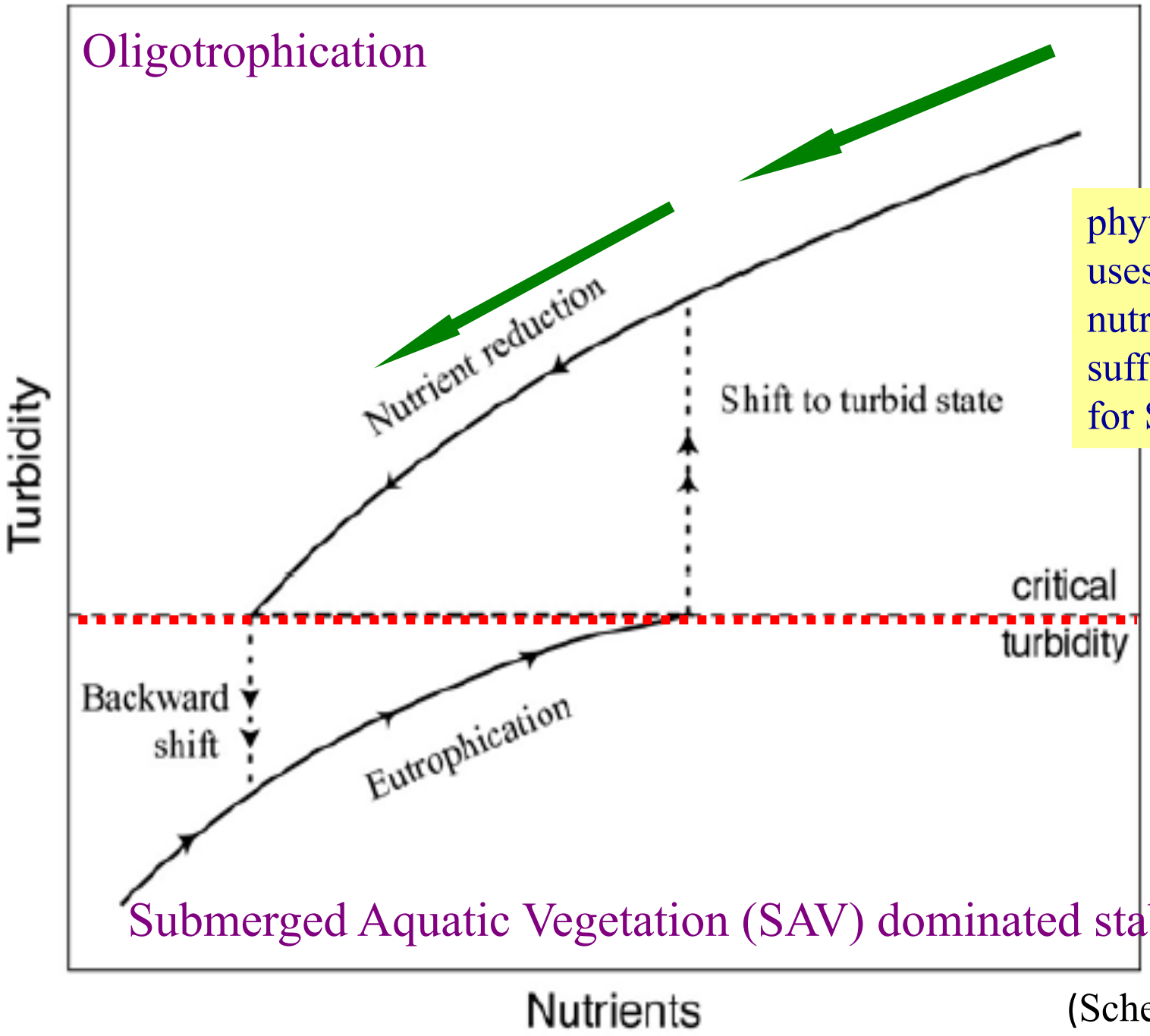
Zostera noltei





(Scheffer 2001)

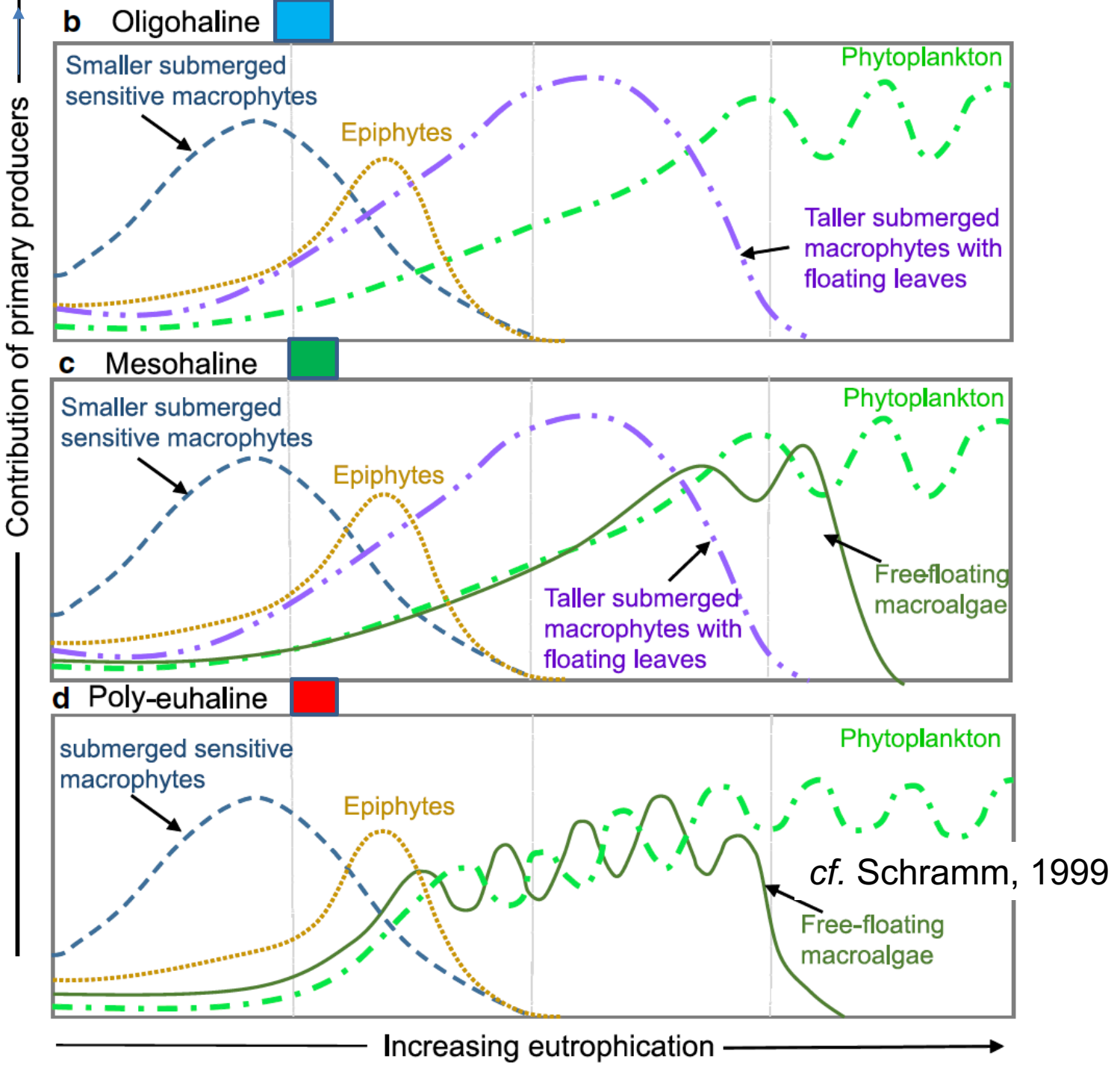

Eutrophication during nutrient over-enrichment
Nutrients are used only by phytoplankton
Sudden increase of phytoplankton by using the nutrients that are previously used by SAV
Nutrient reduction
Shift to turbid state
critical turbidity
Backward shift
Eutrophication
Light intensity becomes too low for SAV
Nutrients are used by SAV and phytoplankton
Submerged Aquatic Vegetation (SAV) dominated stable state
Turbidity
Nutrients
(Scheffer 2001)



phytoplankton uses the nutrients not sufficient light for SAV

Submerged Aquatic Vegetation (SAV) dominated stable state

(Scheffer 2001)



cf. Schramm, 1999

Le Fur et al, 2018, Hydrobiologia

Moving from Eutrophication (1960-2005) to Restoration (oligotrophication / re-oligotrophication / de-eutrophication)

Agglomeration of Montpellier
123 000 inhabitants

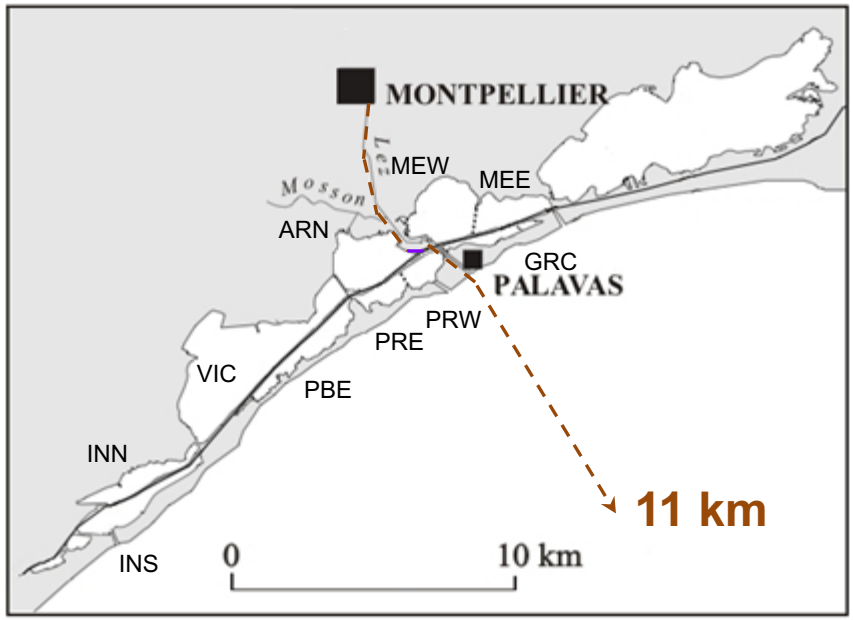
population growth

Agglomeration of Montpellier
450 000 inhabitants

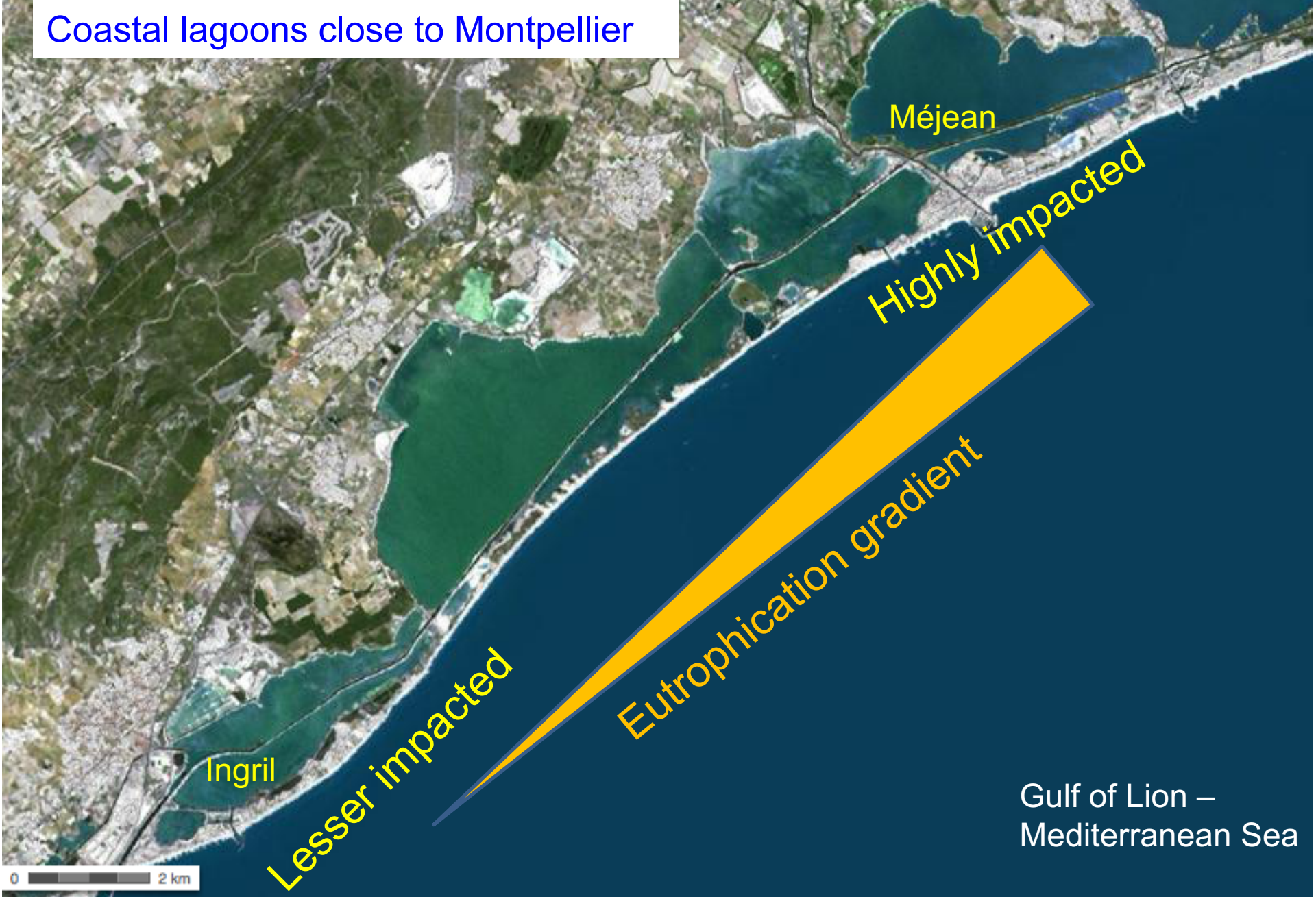
1960 — Coastal urbanization — 2005 — 2013

↗ Anthropogenic inputs to coastal lagoons

12/2005 : Improvement of WWTP and implementation of a 11 km **offshore outfall system** to divert its effluent into the Mediterranean Sea

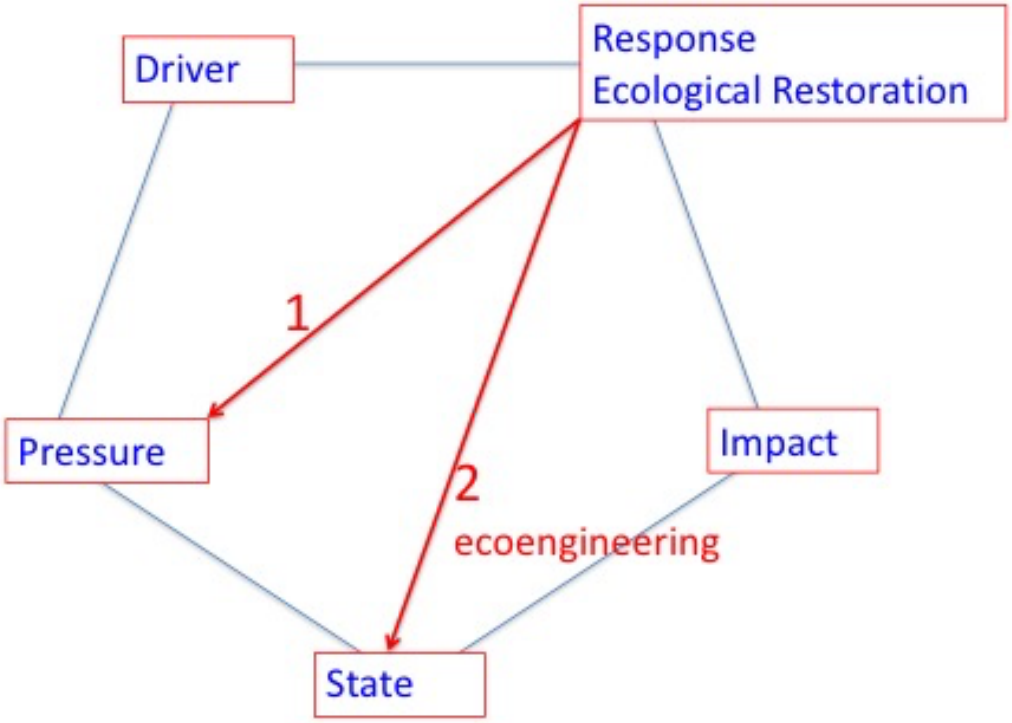


Costs 150 M€, After 2006 reduction of inputs N: 68 % P: 59 %

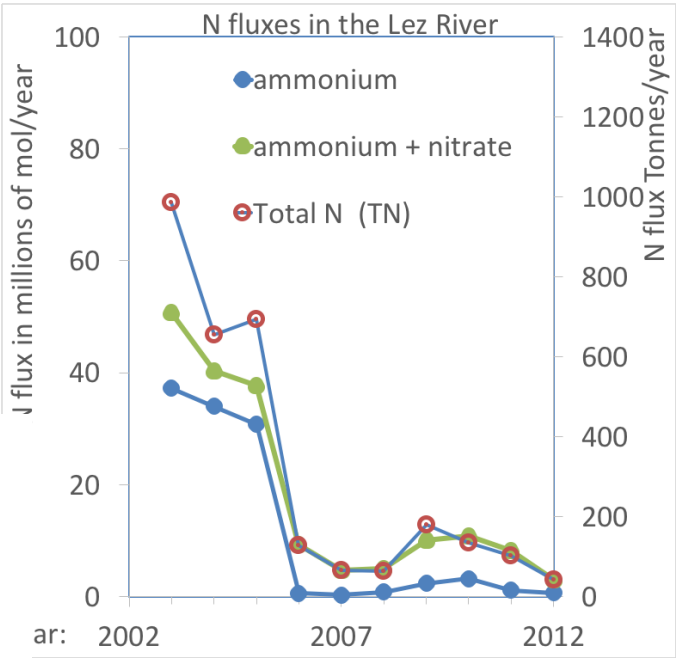

Coastal lagoons close to Montpellier
Méjean
Highly impacted
Eutrophication gradient
Lesser impacted
Ingril
Gulf of Lion –
Mediterranean Sea
0
2 km

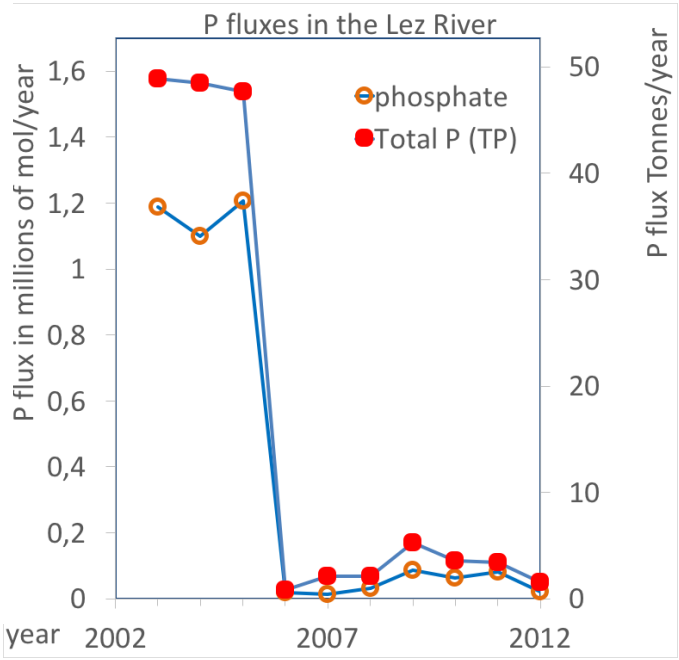
DPSIR

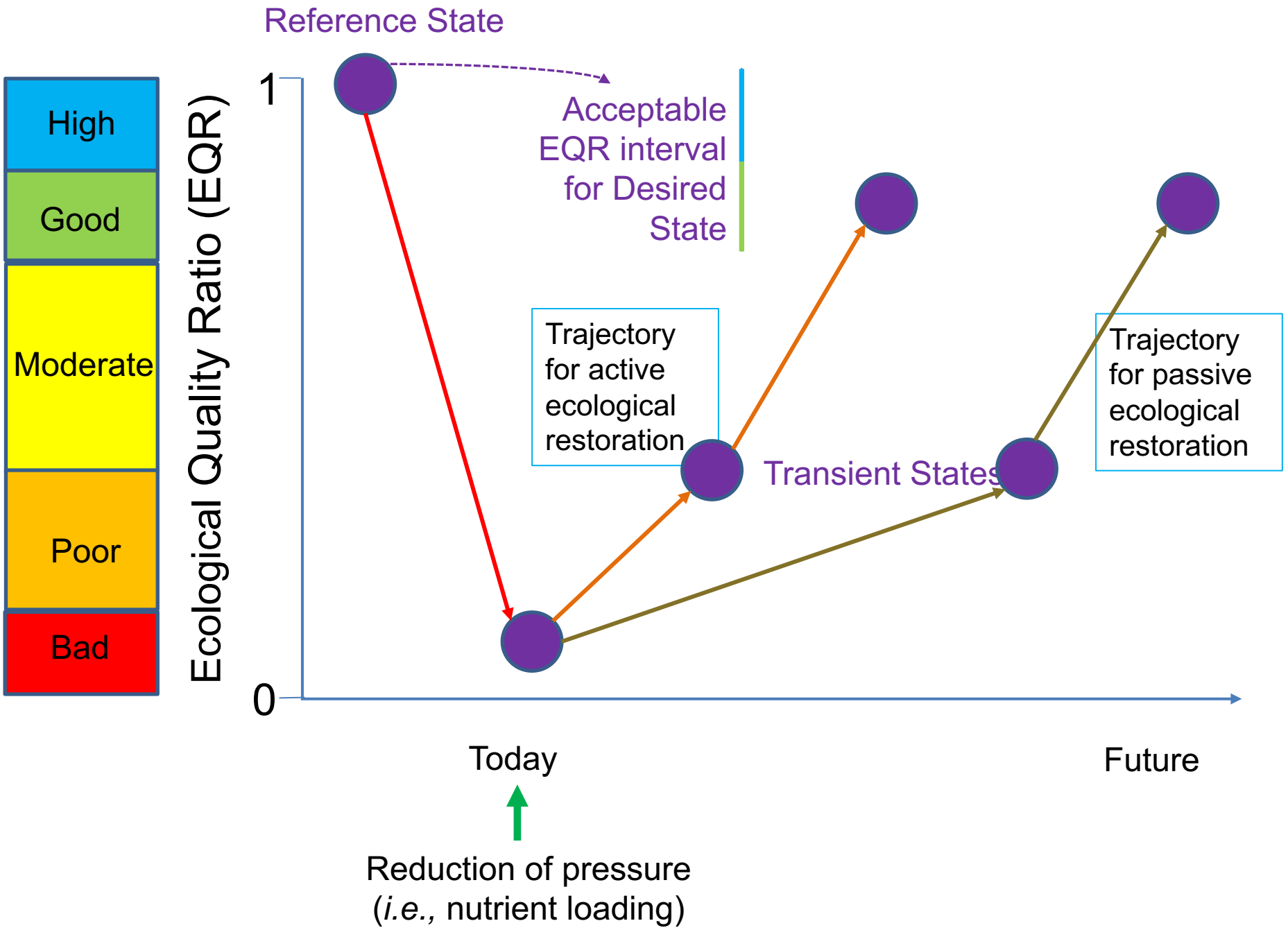
and ecological restoration



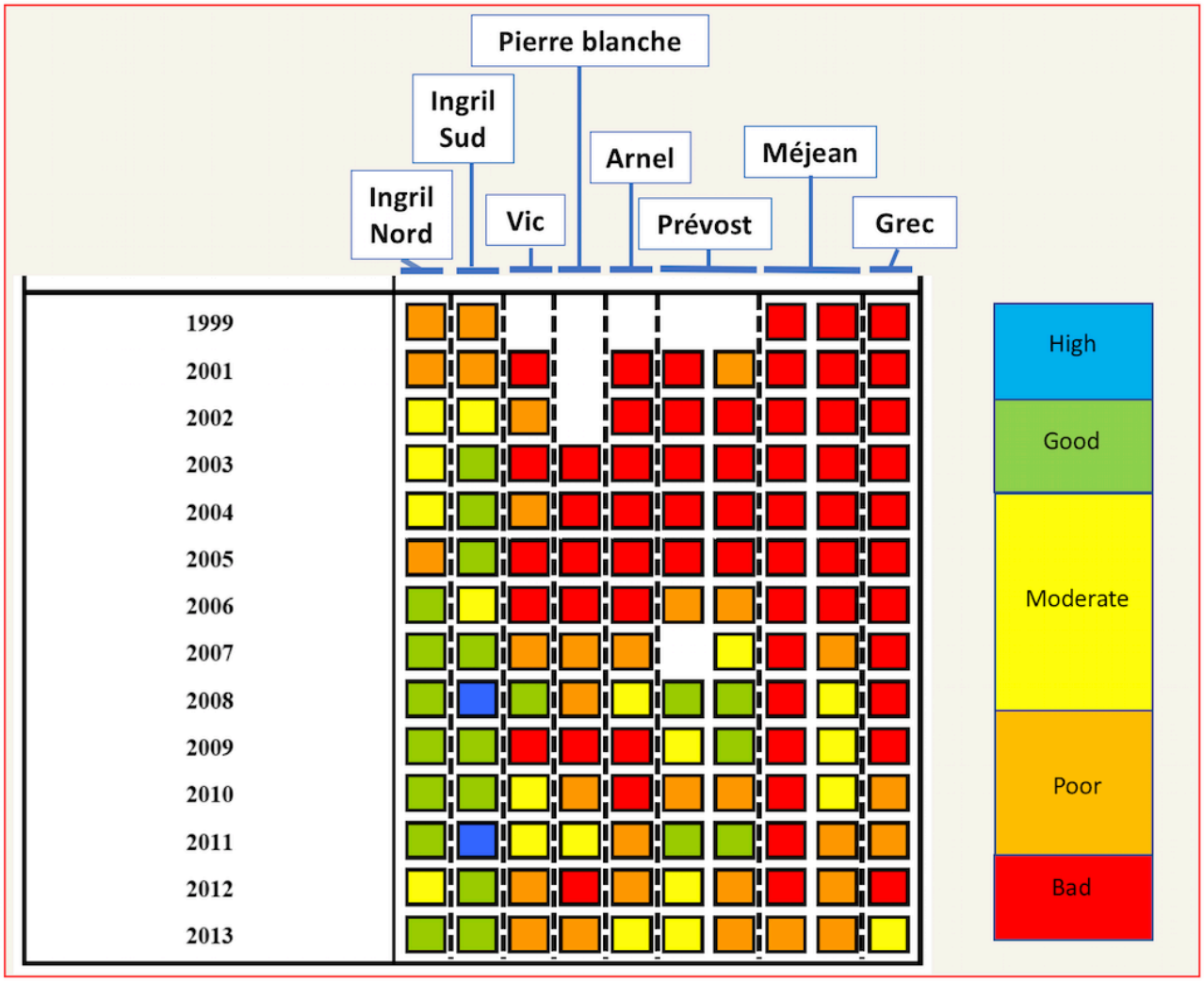
1 alone = passive restoration
2 alone = does not make sense (not sustainable)
1 + 2 = active restoration



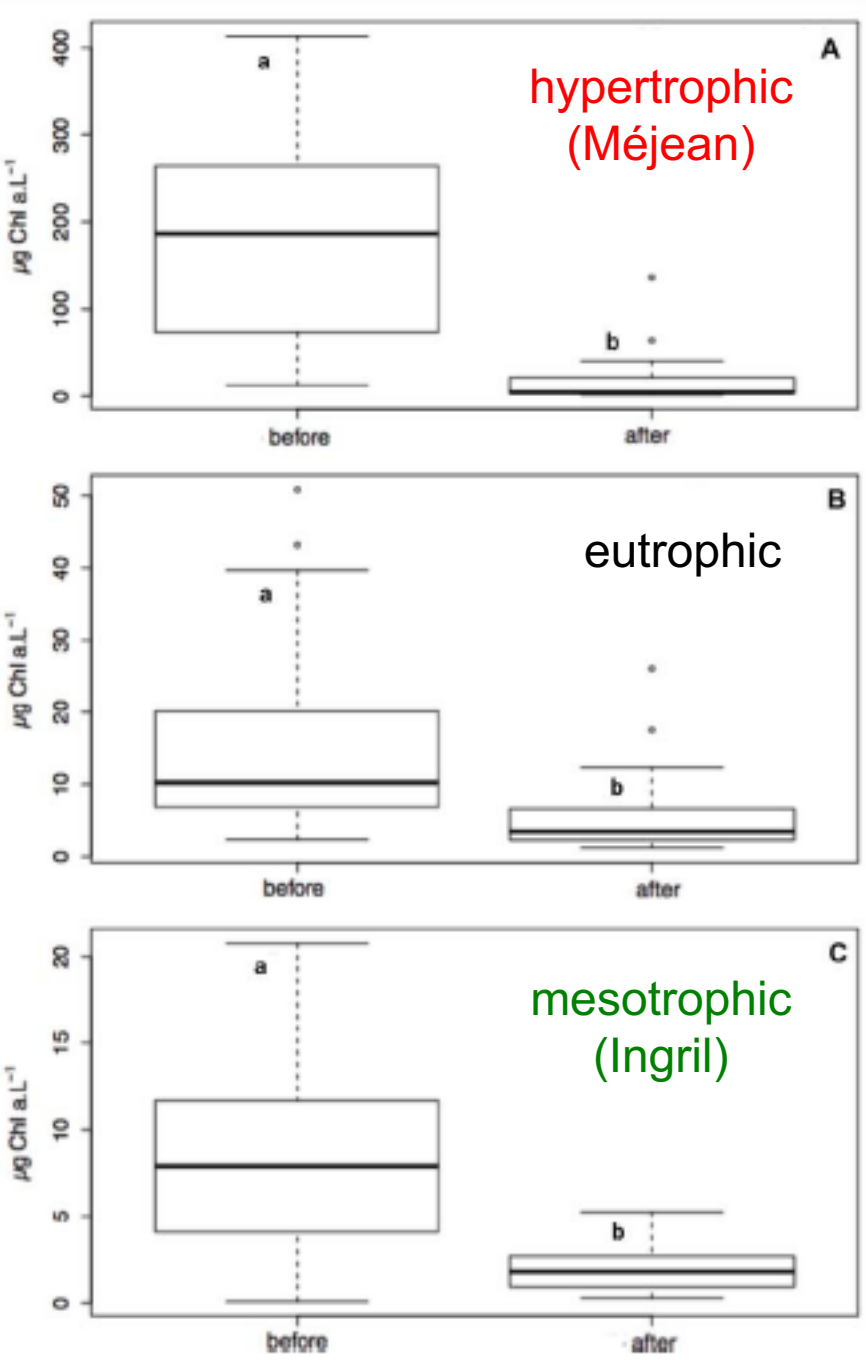



Reference State
High
Good
Moderate
Poor
Bad
Ecological Quality Ratio (EQR)
1
0
Acceptable EQR interval for Desired State
Trajectory for active ecological restoration
Transient States
Trajectory for passive ecological restoration
Today
Future
Reduction of pressure (i.e., nutrient loading)

Indicators for water quality of the RSL monitoring programme (preceding WFD)



Courtesy Ifremer, 2014

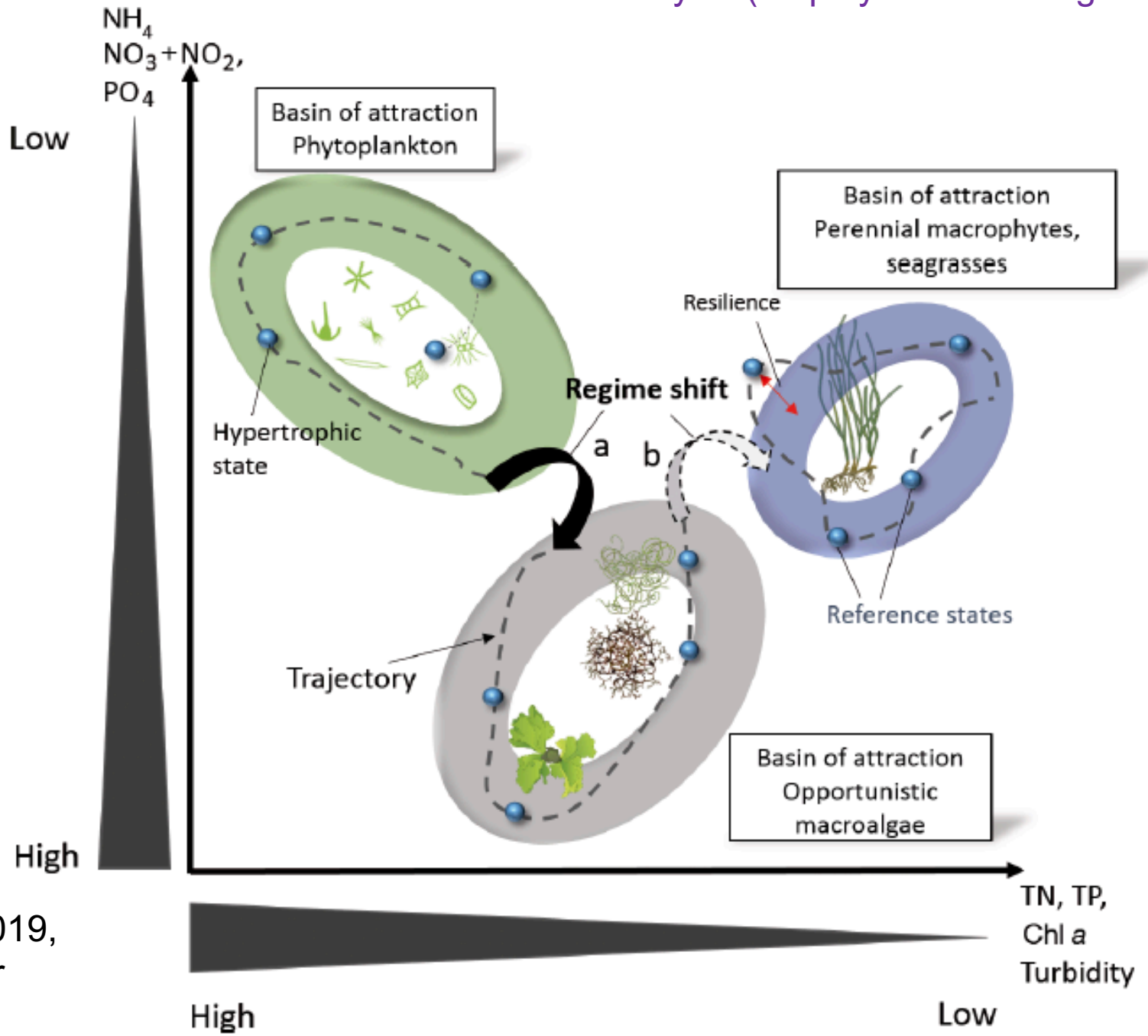


Phytoplankton responds very quickly to oligotrophication

BEFORE = 2000-2005
AFTER = 2006-2013

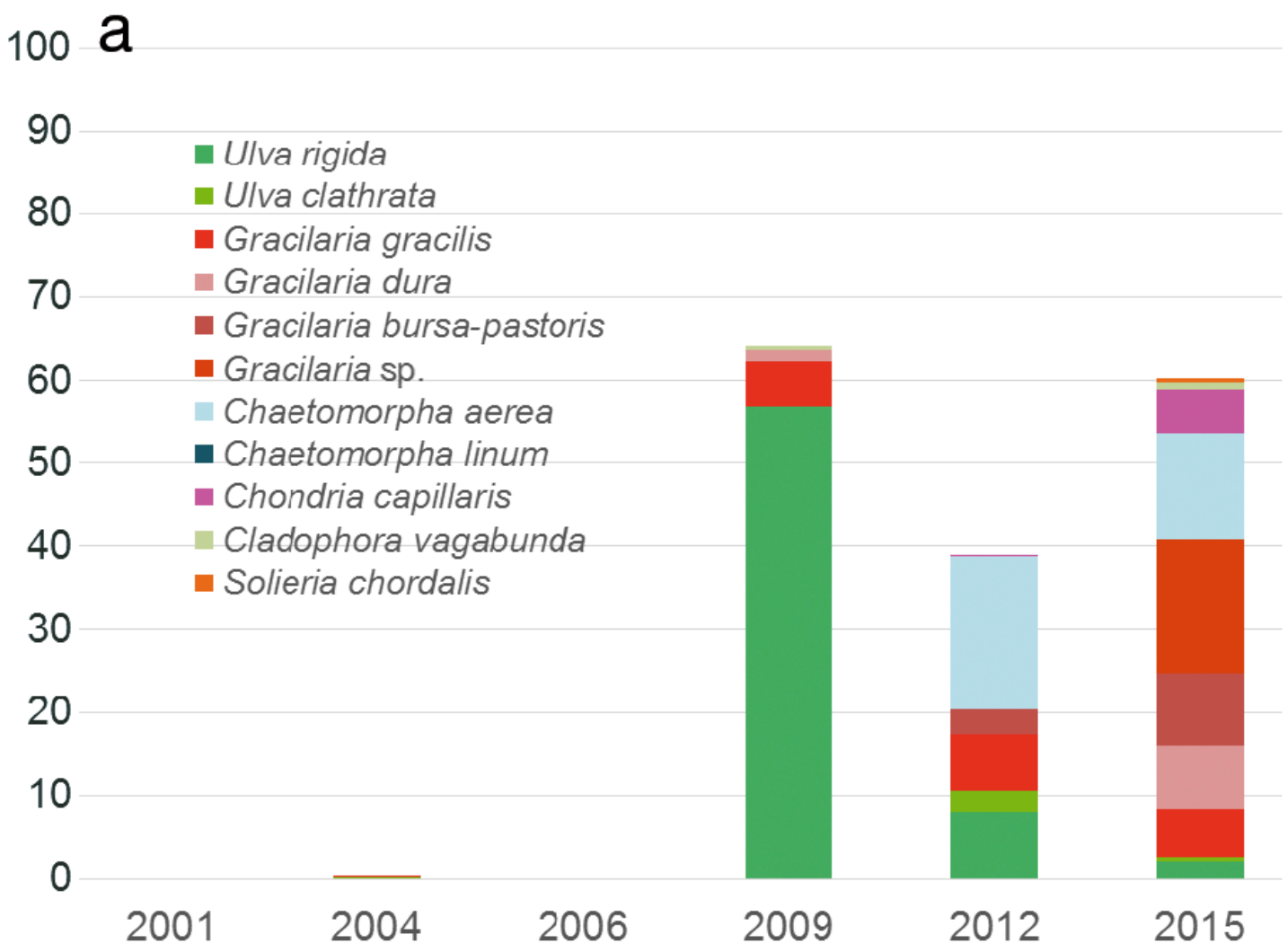
Leruste et al., Estuarine Coastal Shelf Science 2016

Based on STATICO analysis (27 poly- euhaline lagoons)

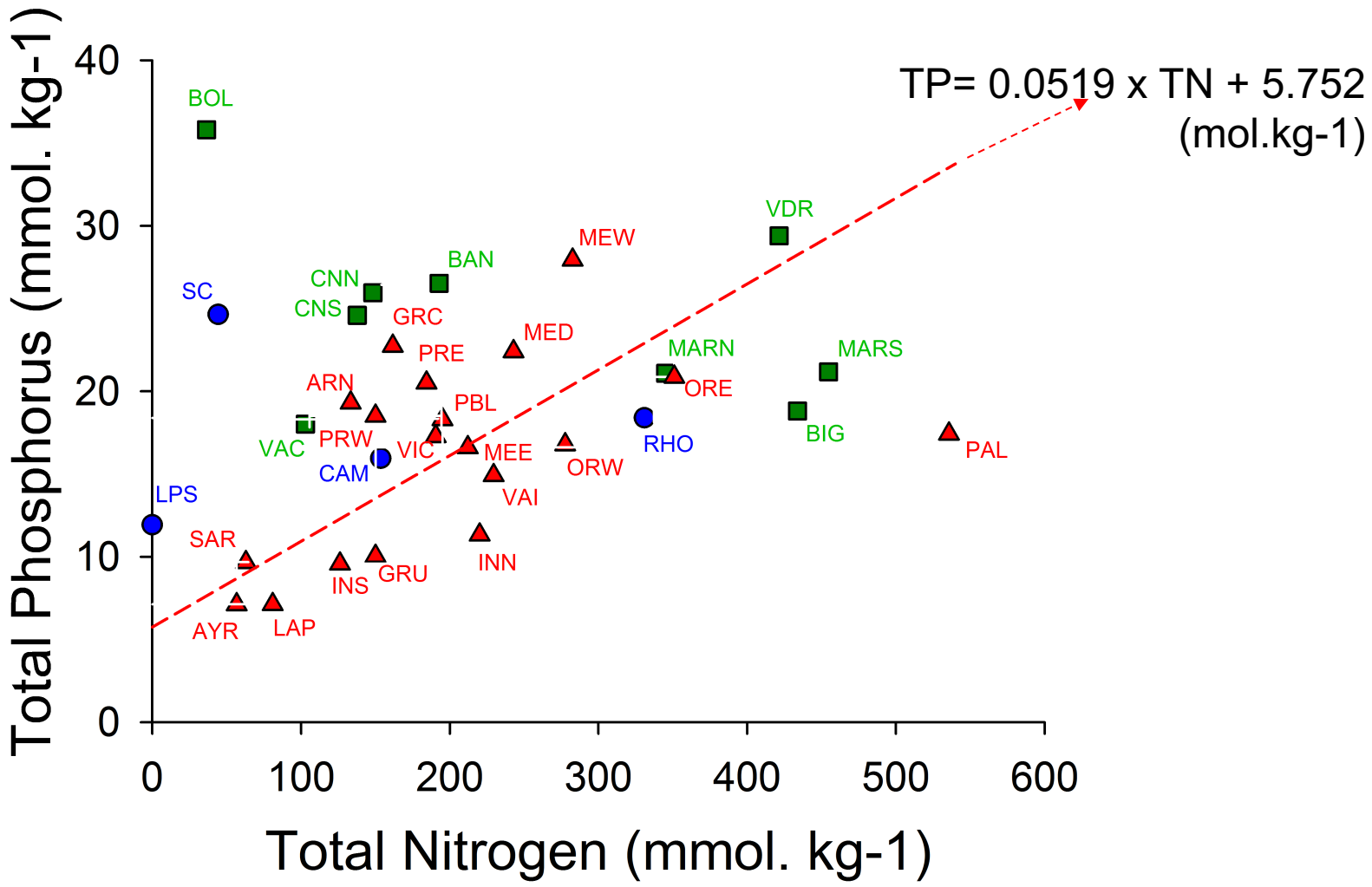


Le Fur et al, 2019, Mar Ecol Progr Series

Macrophytes in Etang de Méjean (BEFORE 2000- 2005 (hypertrophic in 2005) AFTER 2006- 2013)

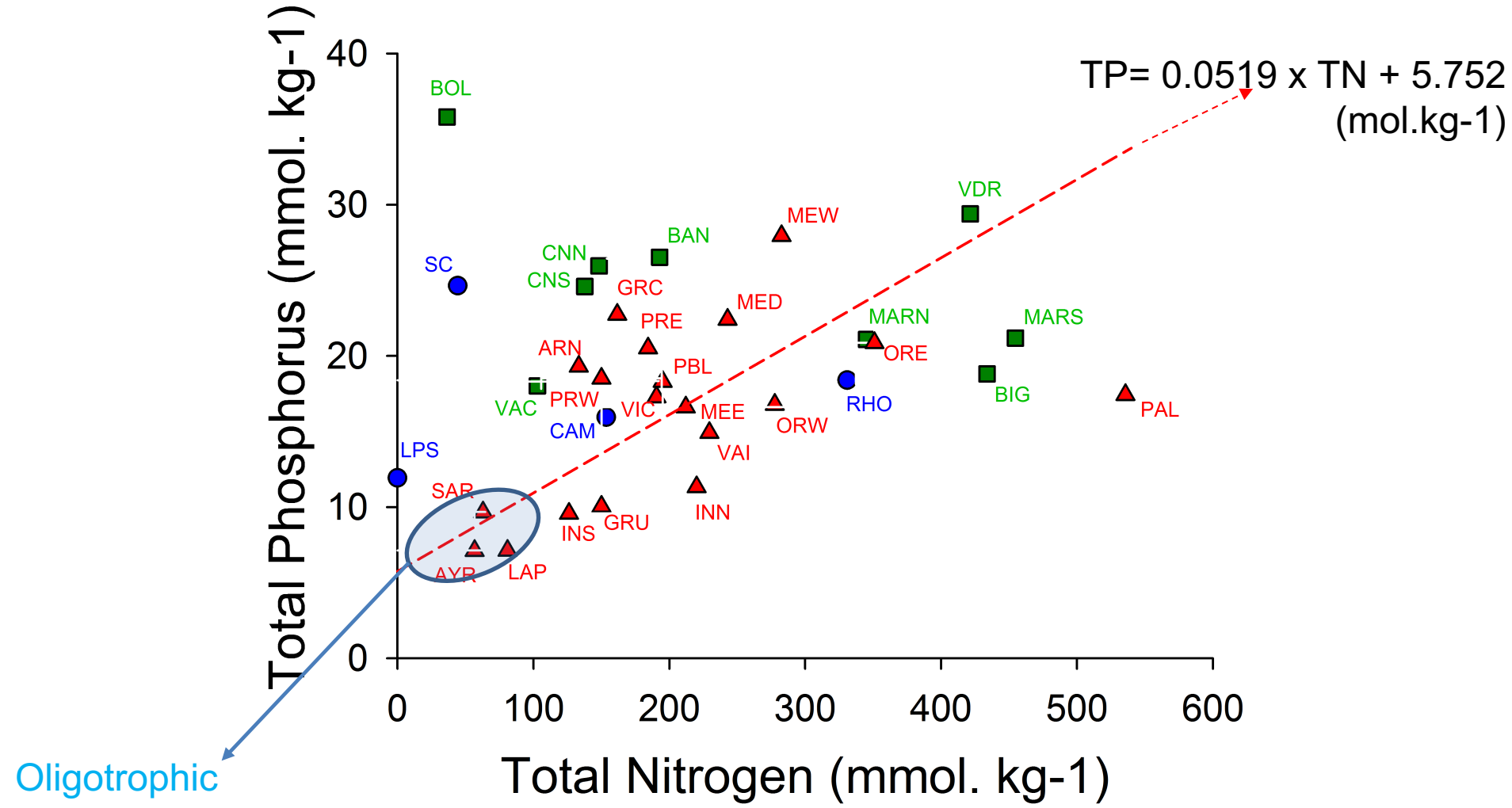


Le Fur et al, 2019, Mar Ecol Progr Series



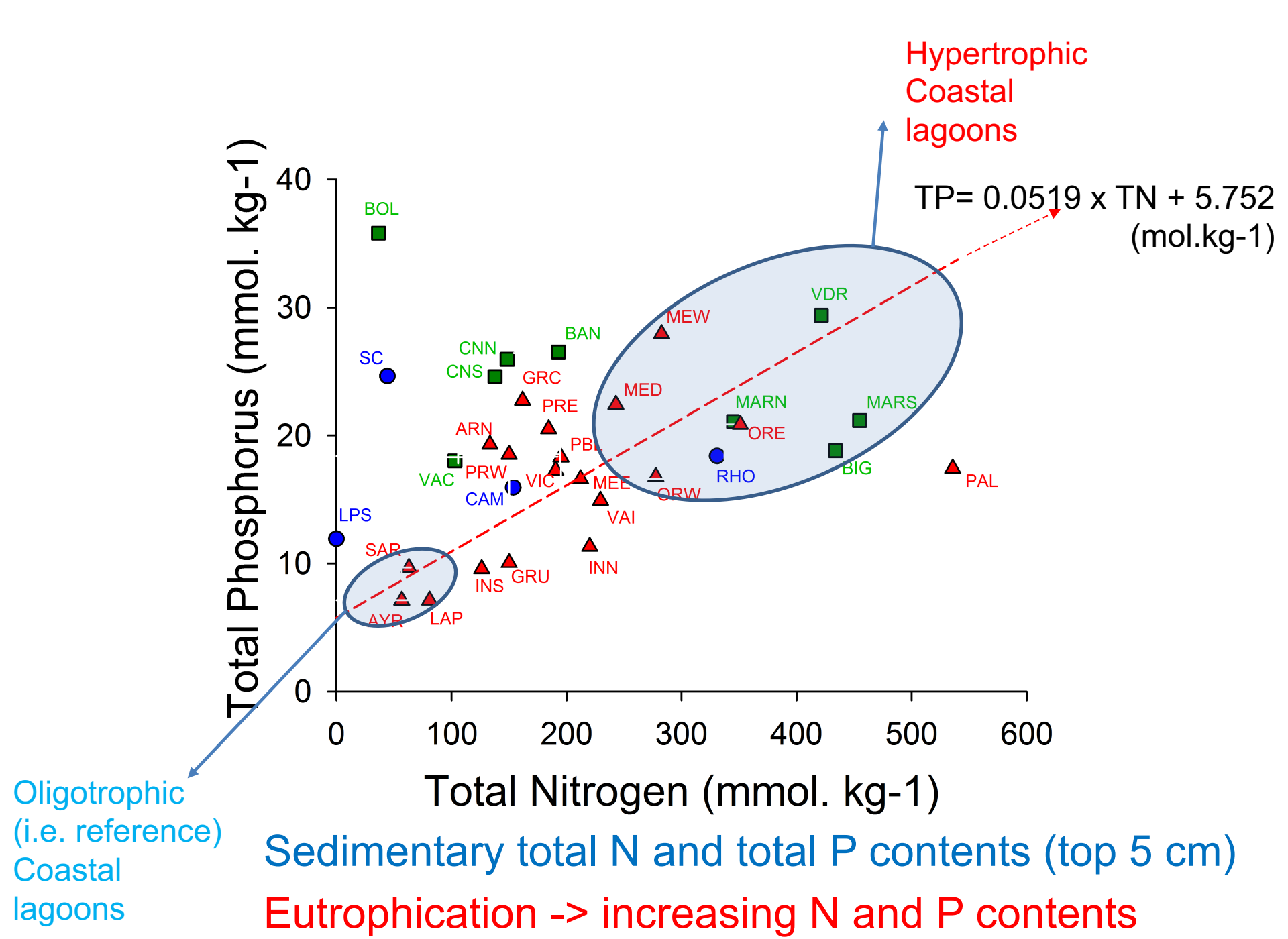
Sedimentary total N and total P contents (top 5 cm)

Eutrophication -> increasing N and P contents

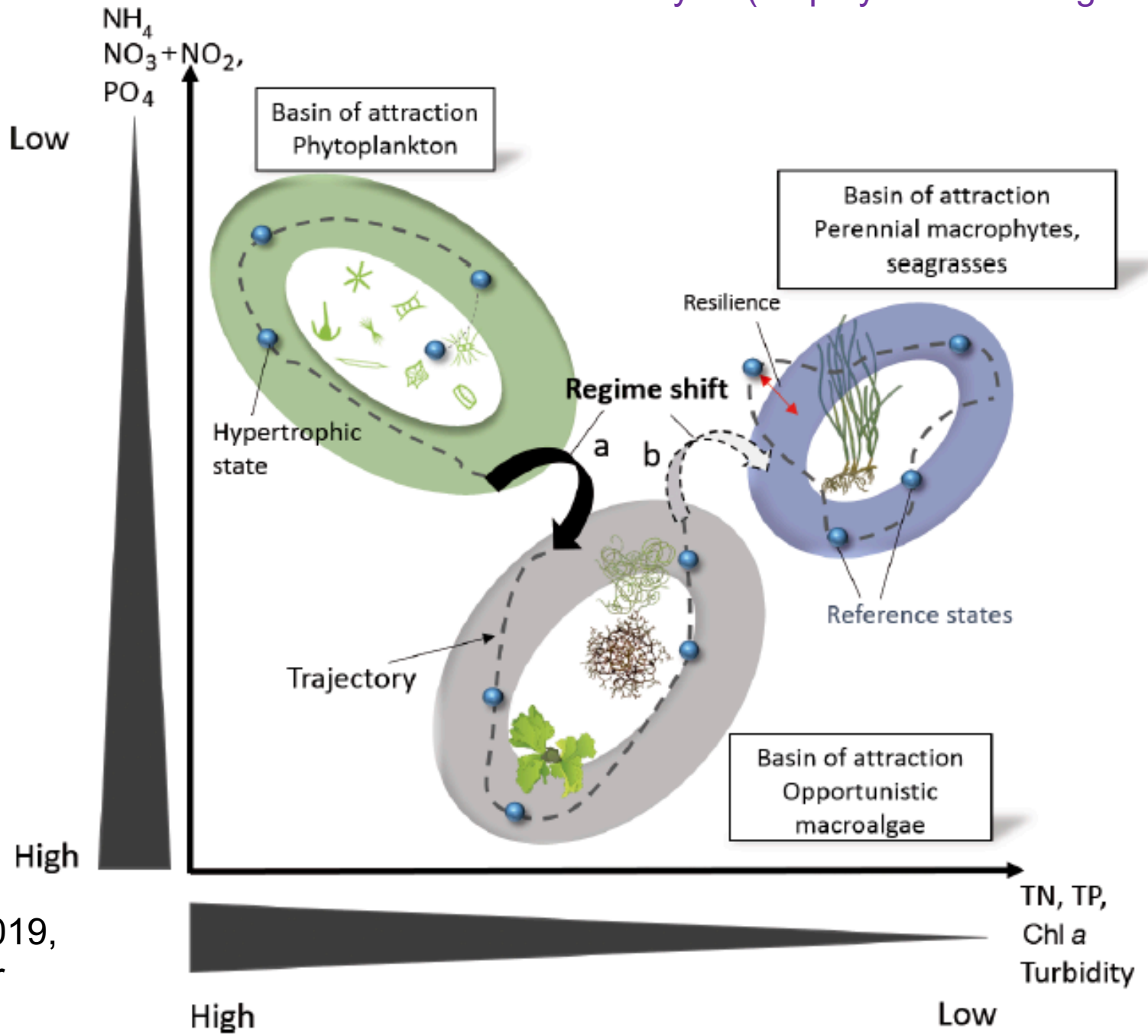


Sedimentary total N and total P contents (top 5 cm)

Eutrophication -> increasing N and P contents


Hypertrophic
Coastal
lagoons
TP= 0.0519 x TN + 5.752
(mol.kg-1)
Total Phosphorus (mmol. kg-1)
Total Nitrogen (mmol. kg-1)
0
10
20
30
40
0
100
200
300
400
500
600
BOL
SC
LPS
CNN
CNS
BAN
GRC
PRE
ARN
PBL
VAC
PRW
VIC
CAM
MEE
VAI
INN
SAR
INS
GRU
AYR
LAP
MEW
VDR
MED
MARN
MARS
ORE
RHO
BIG
ORW
PAL
Oligotrophic
(i.e. reference)
Coastal
lagoons
Sedimentary total N and total P contents (top 5 cm)
Eutrophication -> increasing N and P contents

Based on STATICO analysis (27 poly- euhaline lagoons)

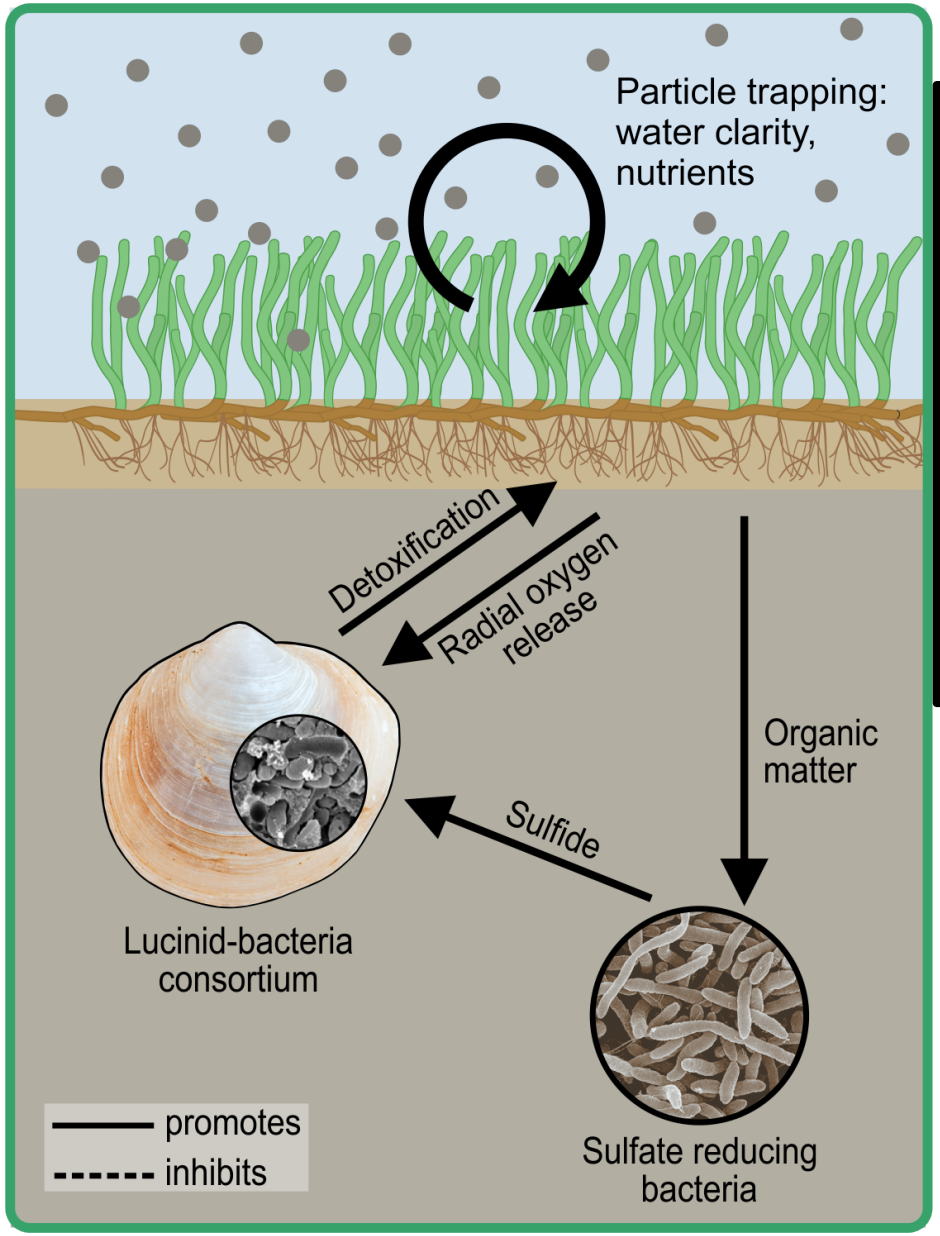


Le Fur et al, 2019, Mar Ecol Progr Series

Laboratory studies: `Van der Heide *et al.* 2012 (Science)

De Fouw *et al.* 2016 (Current Biology)

First field experiment (Thau lagoon) Van der Geest *et al. (in review)*



Seagrass stable state shows positive and negative feedback loops

Negative feedback alleviated by detoxification mutualism

The Scheffer model does it apply in shallow coastal lagoons?

1- **The two end members do occur in coastal lagoons**, i.e.

i) the angiosperm (Magnoliophyta)-dominated state (oligotrophy):

Stuckenia, *Ruppia* sp., *Zostera noltei*

ii) the phytoplankton-dominated state (hypertrophy up to 400 µg.L-1 Chl*a*)

2- In **poly- and euhaline** as well as in **mesohaline** lagoons – macroalgae dominate at intermediate conditions.

3- In mesohaline and oligohaline lagoons some angiosperms (*Ruppia* and *Stuckenia*) **escape competition** with phytoplankton **through floating leaves**.

Oligotrophication trajectories in poly- euhaline lagoons follow a pattern punctuated by regime shifts:

Phytoplankton-dominated state

↓

Macroalgae-dominated state (bottom-dwelling species)

↓

Angiosperm-dominated state

For highly eutrophied conditions the latter regime shift **is difficult to achieve** (has not yet been observed after 10 years of oligotrophication):

-Sediments as an internal source of nutrients

-Feedback loops in the angiosperm-dominated state

Two main questions:

1- is the desired state (WFD) attainable and sustainable?

2- is normative WFD -approach coherent with citizen's desires?

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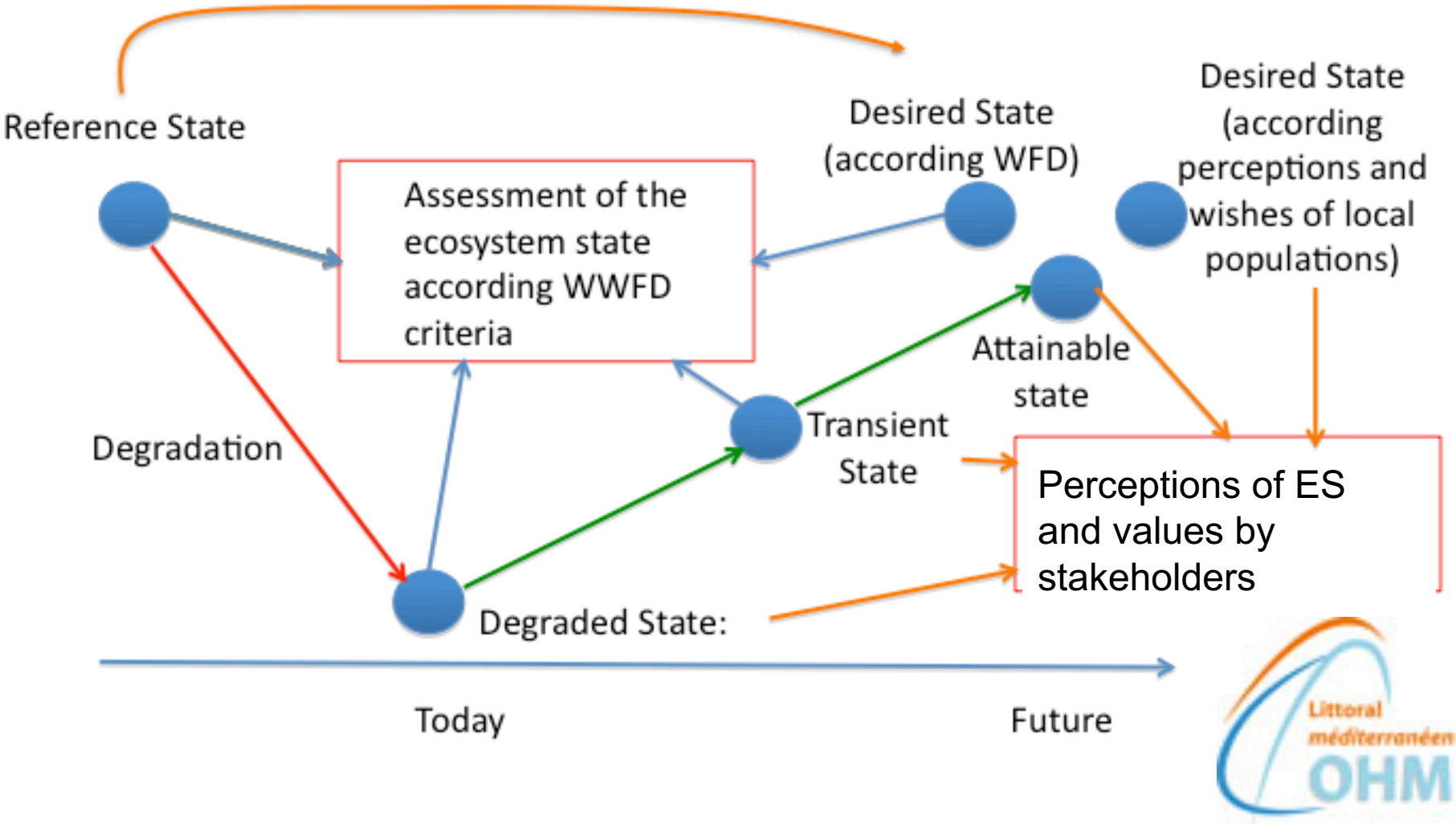
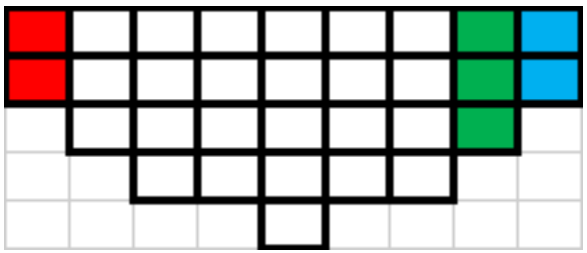


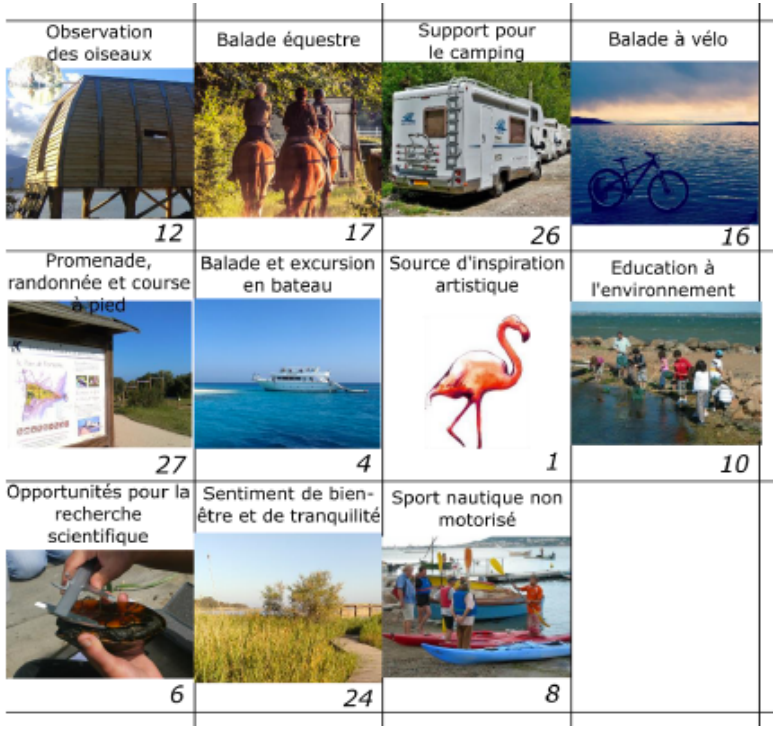
Non-monetary Ecosystem Service assessments

Surveys and
Citizen's workshops

Serious Card game: Q-method

Least (not) Important — Most Important





31 cards with ES for study in Buguglia (Carole Haerty)

Palavas (Sy et al., 2018 Ecol Econ; De Wit et al., under review)

		Highly-involved Stakeholders			Citizens		
		group #1	group #2	group #3	group #1	group #2	group #3
		Environmental hedonic	Environmental teritorial	Environmental and heritage sensitivity	Environmental and territorial approach	Naturalist	Environmental utilitarian - local identity
Regulating and mainteanace	protection against flooding (5)	++	++		++	+	+
	biodiversity + nursery (3)	++	++	++	+	++	
	purification capacity (14)		+	+	++		++
	waste decomposition (20)		+		+		
	bank reinforcement (13)		+				
	microclimate regulation (25)				+		
Cultural services	sentiment of relaxation (24)	+				++	
	hiking and walking (27)	+					
	bird watching (12)					+	
	environmental education (10)	+					
	research opportunities (6)			+			
	local identity (7)			+			
	aesthetic value species & habitats (9)					+	
	aesthetic value of landscape (2)			++			++
	camping (26)	-	-		-	-	-
	waterfowl hunting (18)	-			-	-	
	aesthetic value species & habitats (9)						-
	recreational boat navigation (4)		-				
Provisioning	commercial inland navigation (29)						+
	fish farming (30)			-			
	shellfish farming (22)			-			+

20 ES

- 9 ES – **high-level of consensus** (all 5 regulating ES + 3 cultural ES + 1 provisioning)
- 11 ES (9 cultural ES and 2 provisioning ES)

ES category	ES subcategory	Ecosystem service	Fisher exact test (p value)	General definition
Provisioning	Food provision	**Biomass for grazing**	p < 0.001***	The provision of biomass for human consumption and the conditions to grow it. It mostly relates to cropping, animal husbandry and fisheries.
		Shellfish farming	p < 0.001***	
		Fish resources	0,264	
Regulation and maintenance services	Water provision	*Water purification capacity*	0,298	Biochemical and physicochemical processes involved in the removal of wastes and pollutants from the aquatic environment.
	Coastal protection	*Flooding and other extreme events regulation and protection*	0,235	Protection against floods, droughts, hurricanes, erosion and other extreme events.
		Banks reinforcement	0,196	
	Climate regulation	*Microclimate regulation*	0,393	Regulation of greenhouse and climate active gases. The most common proxies are the uptake, storage and sequestration of carbon dioxide.
	Life cycle maintenance	*Nursery and biodiversity maintenance*	0,281	Biological and physical support to facilitate the healthy and diverse reproduction of species.
Cultural services	Symbolic and aesthetic values	**Aesthetic value of landscapes**	p < 0.001***	Heritage and aesthetic values of the natural environment.
		Local identity	p < 0.001***	
		Aesthetic value of habitats or species	p < 0.001***	
		Historical sites	p < 0.001***	
	Recreation and tourism	**Non-motorized water sports**	p < 0.001***	Opportunities that the natural environment provide for relaxation and amusement.
		Bird watching	p < 0.001***	
		Waterfowl hunting	p < 0.001***	
		Sentiment of relaxation	0.002**	
		Recreational hiking and walking	0,289	
		Recreational fishing	p < 0.001***	
	Cognitive effects	*Research opportunity*	0,869	Trigger of mental processes like knowing, developing, perceiving, or being aware resulting from natural landscapes or living organisms.
		Environmental education	0,464	

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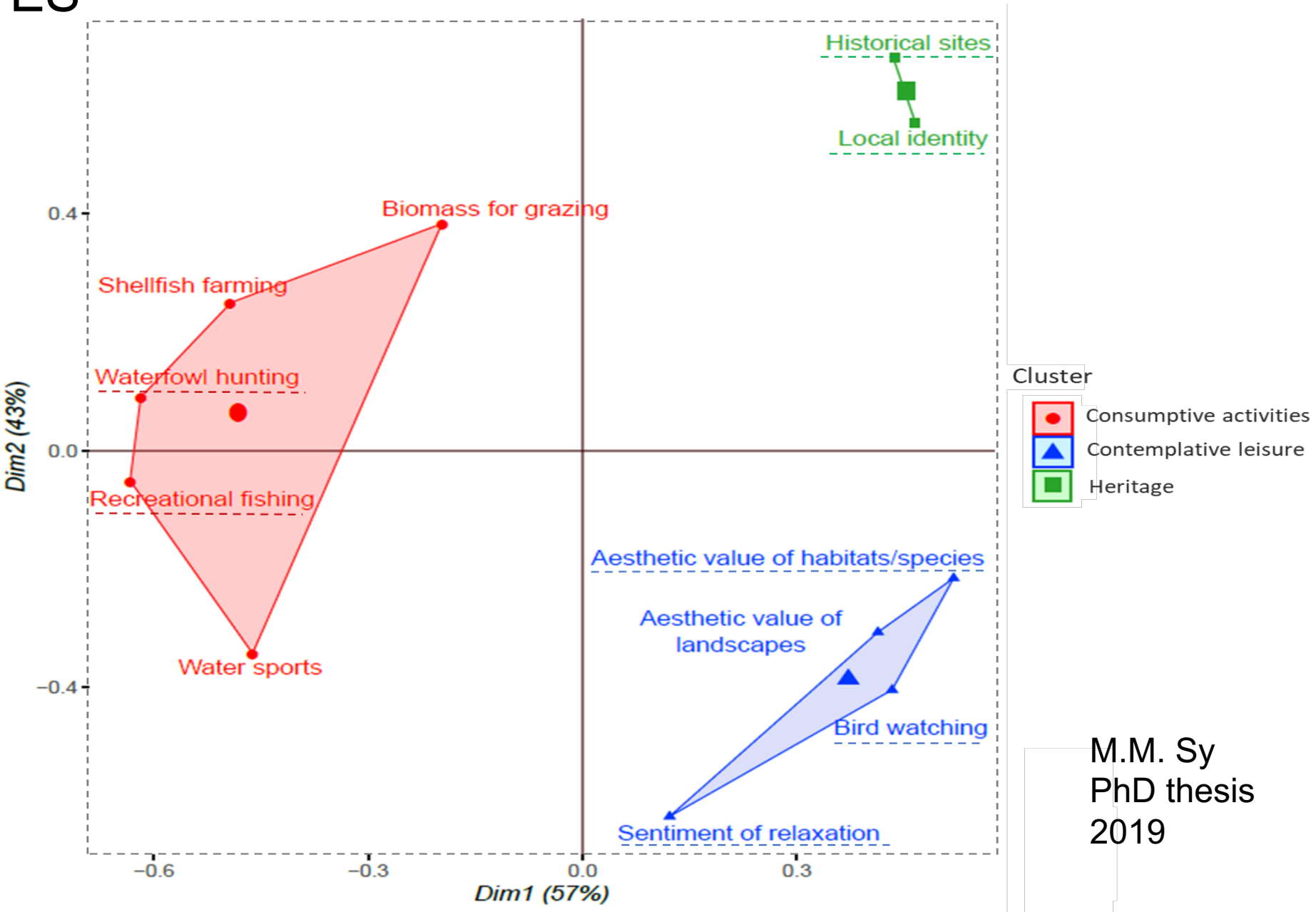
20 ES
- 9 ES – **high-level of consensus** (all 5 regulating ES + 3 cultural ES + 1 provisioning)
- 11 ES (9 cultural ES and 2 provisioning ES)

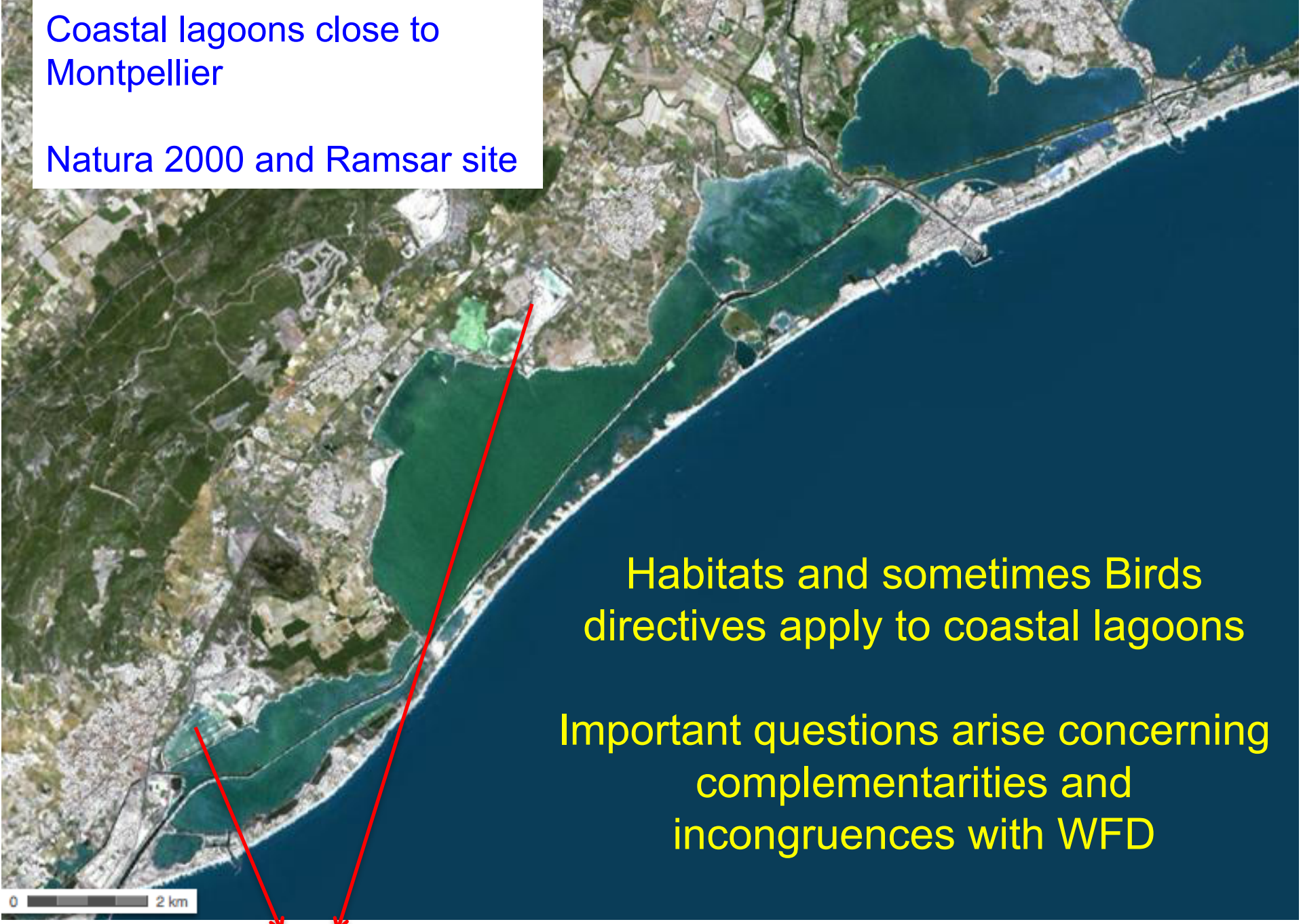


M.M. Sy
PhD thesis
2019

- **stakeholders share a strong consensus concerning the importance of regulating ES**
  - (environmental/territorial profiles give highest priority to regulating ES)

- **In contrast, concerning cultural ES, different stakeholder profiles can be recognized:`**

  - naturalists profiles based on a **contemplative approach of nature** (leisure) are opposed to
  - a profile that favours **consumptive use of nature combined with a sense of local identity**.


Coastal lagoons close to Montpellier
Natura 2000 and Ramsar site
Habitats and sometimes Birds directives apply to coastal lagoons
Important questions arise concerning complementarities and incongruences with WFD
0
2 km
Abandoned Salinas

Habitats Directive (coastal lagoons = priority habitat 1150)

Includes abandoned salt concentration ponds when constructed in former lagoons

R. De Wit, et al.

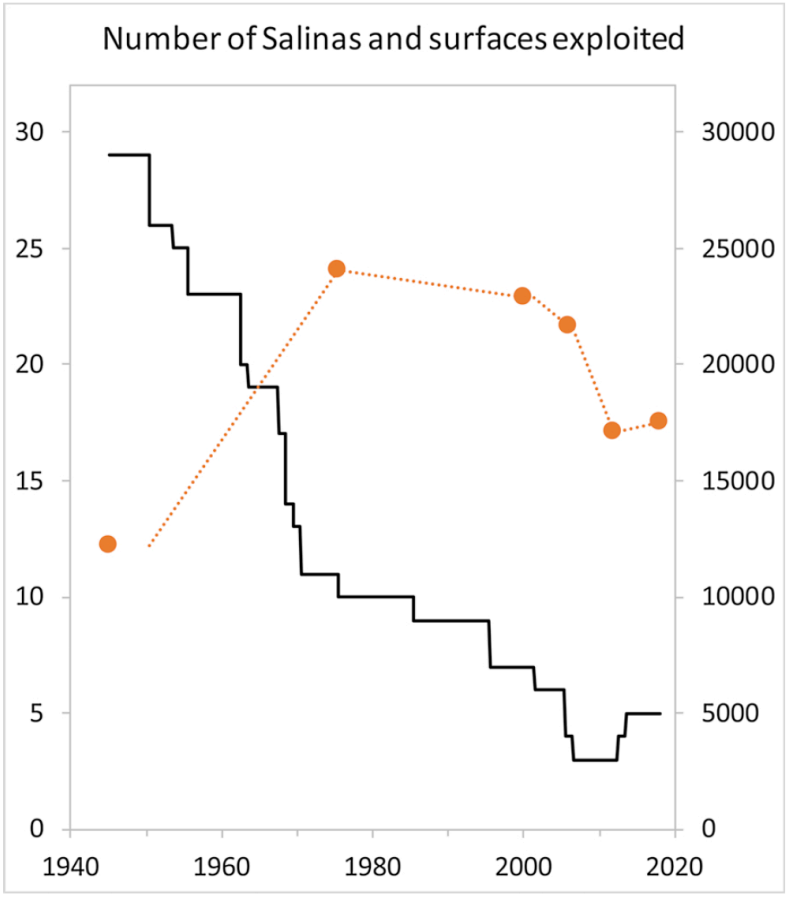
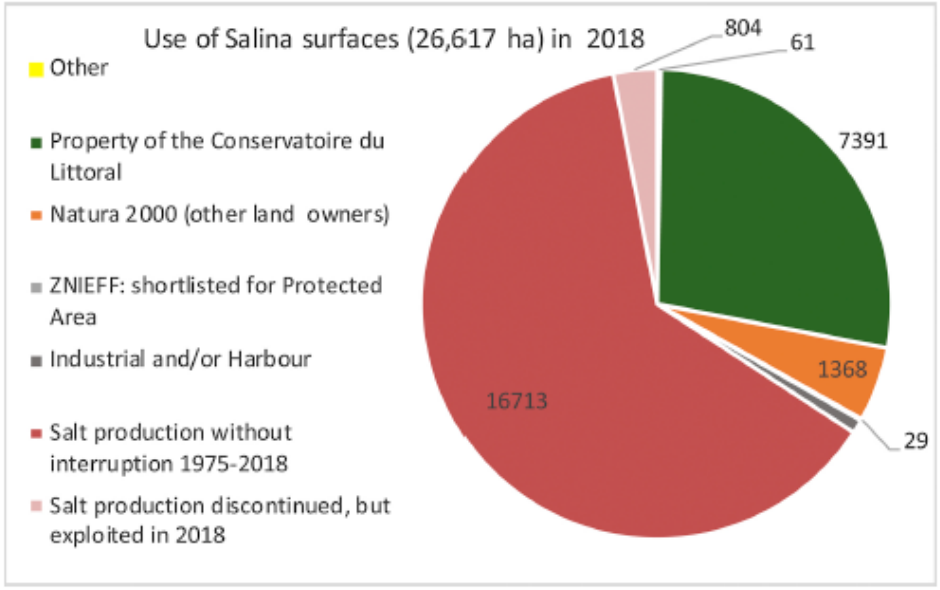


Fig. 4. Time course of the total number of exploited Salinas (black line, left scale) and surfaces used in hectares (closed circles, right scale) for salt extraction along the Mediterranean coast in southern France between 1950 and 2018.



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Monitoring: data

Ifremer

Littoral méditerranéen OHM