THE AQUATIC MACROPHYTES OF GREEK LOWLAND RIVER SYSTEMS:

Assessing the ecological status in response to morphological degradation

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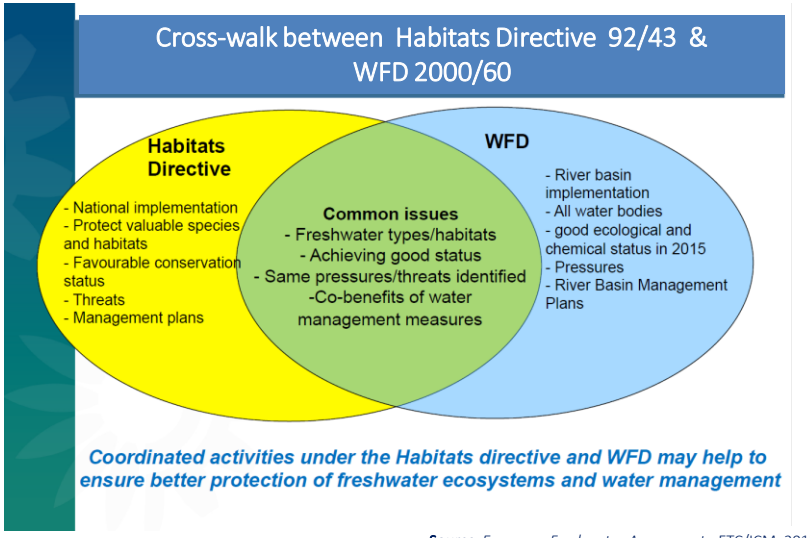
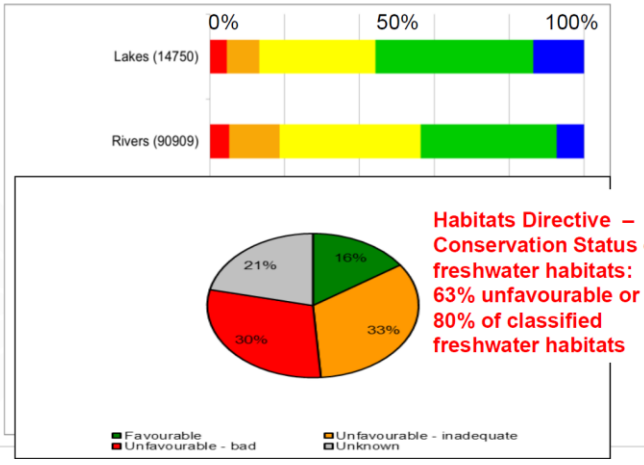
EU POLICIES ON FRESHWATER ENVIRONMENT, NATURE & BIODIVERSITY



Source: *European Freshwater Assessment* , ETC/ICM 2015

WFD and HD status – EU level

WFD – ecological status in classified rivers: 55% < good, 40% of lakes < good

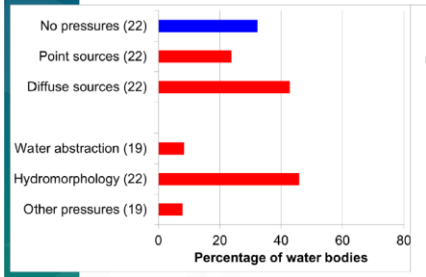


Habitats Directive – Conservation Status of freshwater habitats: 63% unfavourable or 80% of classified freshwater habitats

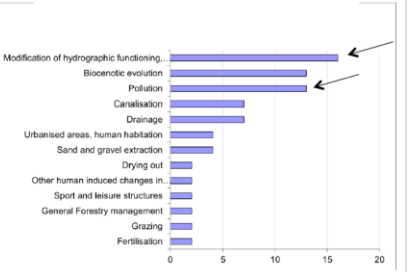
Source: *European Freshwater Assessment* , ETC/ICM 2015

WFD pressures and HD threats: EU-level

WFD: Rivers affected by specific pressures



Freshwater Habitat types affected by specific pressures



Pollution (mainly nutrients) and hydromorphological modifications most important in both directives

Source: *European Freshwater Assessment* , ETC/ICM 2015

WFD Biological **Q**uality **E**lements - ***Macrophytes***

- freshwaters plants, easily seen with the naked eye & considered as appropriate indicators of ecological quality in aquatic ecosystems
- Importance of macrophytes in Biological assessment is formally recognized under **WFD 2000/60/EC,** in which macrophytes are one of four Key **B**iological **Q**uality **E**lements (**BQE**'s) for monitoring the ecological status of surface waters
- Under **WFD** each Member State is required to devise a comprehensive ***N**ational **M**onitoring **P**rogramme* for surface waters, incorporating hydromorphological, physicochemical & Biological Elements

WFD Biological **Q**uality **E**lements - ***Macrophytes***

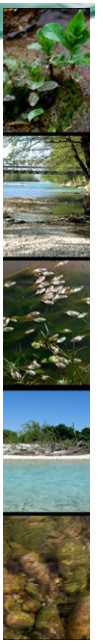
In the above framework, we are working in:

- a method for monitoring ecological quality of **Greek** rivers using macrophytes &
- intends to investigate the relationship between ecological quality, macrophyte assemblages & habitat degradation

National Monitoring Project- ***macrophytes***

- The **Greek** *National Monitoring Network* for *Macrophytes* consists of almost **100** lowland river sites belonged to **RM-1, RM-2** (Small/ Medium lowland streams) & **RM-3** (Large lowland rivers) **I**ntercalibration **C**ommon (IC) types

- The sampling sites are located at the greatest extent of **Greek** territory
- **Field** monitoring campaigns conducted in Spring–Summer during the period of 2014-2015



National Monitoring Project- ***macrophytes***

Timeline

2014

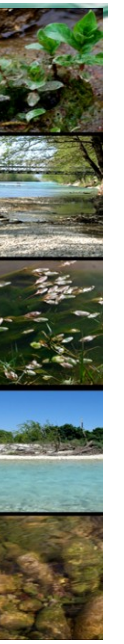
- Aug - Sept — Phase A - Sampling
- November — Phase A data elaboration – paperwork

2015

- April — Phase A - Completed
- May — Phase B started
- June- Sept — Phase B - Samplings
- December — Phase B completed

2016

- January — Phase C started ..... *more river sites*



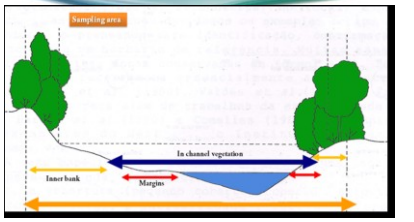
National Monitoring Project- ***macrophytes***

- Data from the rivers basin area were collected using the **MEDGIG** standardized protocol
- Physicochemical, hydromorphological & **macrophyte species data** were collected and analyzed from all surveyed sites:
  - ✓ Presence & abundance were estimated according to **MEDGIG** suggested 5-point abundance scale
  - ✓ **Aquaticity** (links to water): 1- Exclusively aquatic species to 7- Woody riparian species
  - ✓ **Floristic groups**: e.g. ALG-Algae, PTE-Pterophytes, BRm-Bryophytes, Phe-Helophytic phanerogams (emersed), Phy- Hydrophytic phanerogams (submerged or floating species)

Sampling procedure

✘ All plants found in **channel**, **margins** & **inner bank**

✘ **100 m** river length



List of **macrophyte** species and their **floristic groups**

			Site 1	Site 2	Site 3	Site 4	Site 5
National Site Code			S1	S2	S3	S4	S5
IC Code			GR_001_06/07	GR_002_06/07	GR_003_06/07	GR_004_06/07	GR_005_06/07
Location (C1, C2,C+B)			C+B	C+B	C+B	C+B	C+B
Survey area [m²]			30	30	30	30	2600
Taxon Name	**Floristic Group**	**Aquaticity*****					
Acer campestre	LIG	7					
Ajuga reptans	PHg	4					2
Alisma lanceolatum	PHe	4					
Alisma plantago aquatica	PHe	4					
Alnus glutinosa	LIG	7					
Alopecurus geniculatus	PHx	6					
Anomodon viticulosus	BRm	3				4	
Amblystegium humile	BRm	3					
Amblystegium riparioides	Brm	3					

IBMR- Macrophyte Biological Index for Rivers

$$IBMR = \frac{\sum_i (E_i \cdot K_i \cdot CS_i)}{\sum_i (E_i \cdot K_i)}$$

Metrics:

K = abundance (translated in 5 classes), CS = trophic score (0-20), E = stenoecy coefficient (1-3)

IBMR = Σ(K.CS.E)/Σ(K.E)

IBMR- Macrophyte Biological Index for Rivers

assessment method that was finalized & formally agreed for the IC of MedGIG highly seasonal rivers

Overview of broad European river types

Broad river type name	Broad river type code	Altitude (masl)	Catchment area (km²)	Geology	number of national types	number of WBs	% of WBs
Very large rivers (all Europe)	1	any	>10 000	any (usually mixed)	54	827	1,0 %
Lowland, Siliceous, Medium-Large	2	≤200	100 - 10 000	Siliceous	24	1139	1,4 %
Lowland, Siliceous, Very small-Small	3	≤200	≤100	Siliceous	30	7302	8,9 %
Lowland, Calcareous or Mixed, Medium-Large	4	≤200	100 - 10 000	Calcareous/Mixed	67	2872	3,5 %
Lowland, Calcareous or Mixed, Very small-Small	5	≤200	≤100	Calcareous/Mixed	47	14137	17,1 %
Lowland, Organic and Siliceous	6	≤200	<10 000	Organic and Siliceous	18	6193	7,5 %
Lowland, Organic and Calcareous/Mixed	7	≤200	<10 000	Organic and Calcareous/ Mixed	9	336	0,4 %
Mid altitude, Siliceous, Medium-Large	8	200 - 800	100 - 10 000	Siliceous	41	3051	3,7 %
Mid altitude, Siliceous, Very small-Small	9	200 - 800	≤100	Siliceous	37	8627	10,5 %
Mid altitude, Calcareous or Mixed, Medium-Large	10	200 - 800	100 - 10 000	Calcareous/Mixed	61	1797	2,2 %
Mid altitude, Calcareous or Mixed, Very small-Small	11	200 - 800	≤100	Calcareous/Mixed	48	7663	9,3 %
Mid-altitude, Organic and siliceous	12	200 - 800	<10 000	Organic and Siliceous	8	3290	4,0 %
Mid-altitude, Organic and Calcareous/Mixed	13	200 - 800	<10 000	Organic and Calcareous/ Mixed	6	154	0,2 %
Highland (all Europe), Siliceous, incl. Organic (humic)	14	>800	<10 000	Siliceous	16	1525	1,8 %
Highland (all Europe), Calcareous/Mixed	15	>800	<10 000	Calcareous/Mixed	17	2227	2,7 %
Glacial rivers (all Europe)	16	> 200	<10 000	any	16	3251	3,9 %
Mediterranean, Lowland, Medium-Large, perennial	17	≤200	100 - 10 000	any	16	941	1,1 %
Mediterranean, Mid altitude, Medium-Large, perennial	18	200 - 800	100 - 10 000	any	13	615	0,7 %
Mediterranean, Very small-Small, perennial	19	< 800	≤100	any	21	1942	2,4 %
Mediterranean, Temporary/Intermittent streams	20	any	<1 000	any	26	3549	4,3 %
				Total	575	71438	86,6 %

Source: *European Freshwater Assessment* , ETC/ICM 2015

National Monitoring Project- ***macrophytes***

Typology

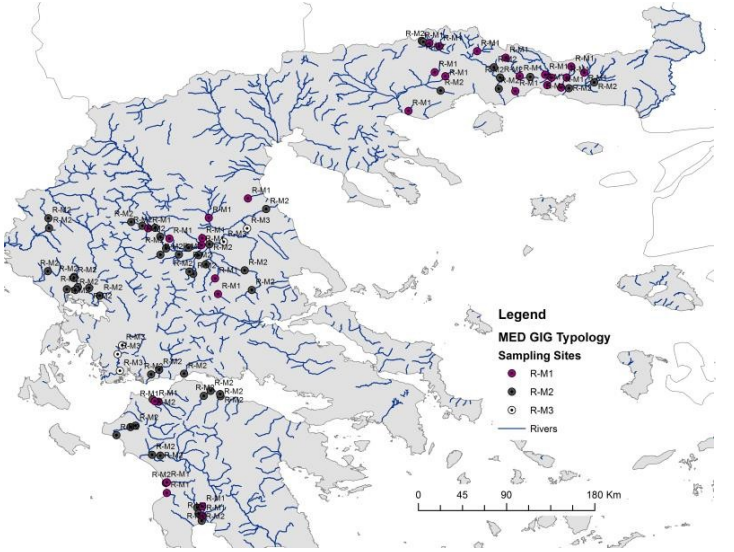
MEDGIG

R-M1	Small Mediterranean streams (<100 km² mixed, except siliceous)
R-M2	Medium Mediterranean streams (100-1000 km² mixed, except siliceous)
R-M3	Large lowland (>10.000km², mixed, except non- siliceous)
R-M4	Mediterranean mountain streams (highland, non-siliceous)
R-M5	Mediterranean Temporary streams

NATIONAL

Bioregions (Biogeographical areas)	**I:** **S:** **N:**	Ionian South Greece North Greece
Indicative runoff (basin size, rainfall, runoff factor: geology, vegetation)	**s:** **m:** **g:**	Small Medium/big Great
Altitude	**L:** **H:**	Low/medium High
Gradient (slope, stream flow)	**1:** **0:**	Fast Low

Sampling Sites in Greek rivers (MEDGIG)




IsL1


NsL1
2015 8 30 17:50


SsL1
2015 4 18 12:10


ImL1
2015 8 5 10:55

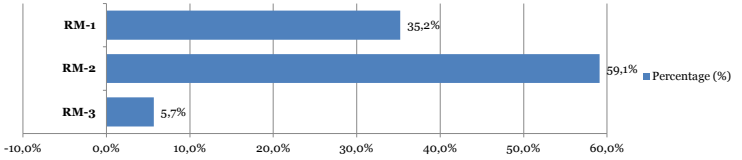

NmL0
2015 4 17 12:25


NmL1

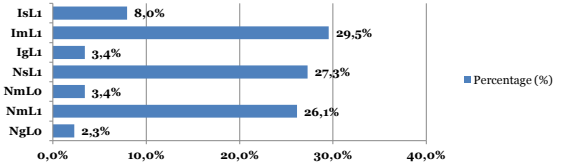

IgL1


NgLo
2015. 4.16 16:24

MEDGIG Types



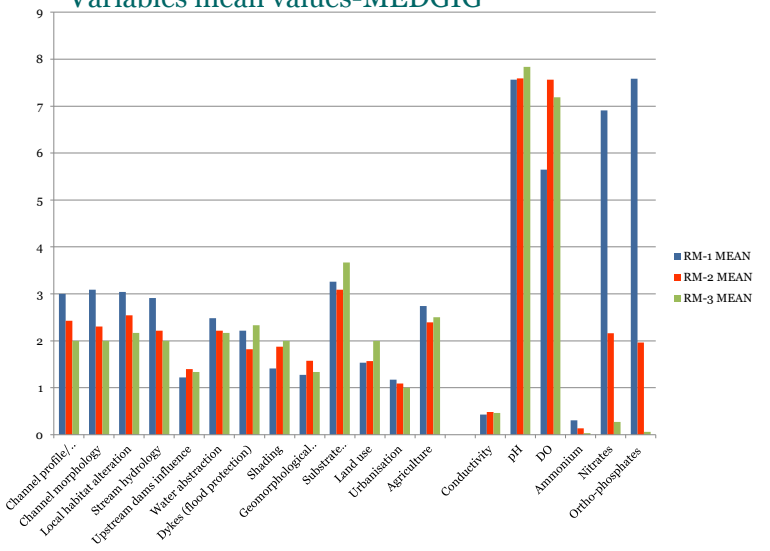
NATIONAL Types



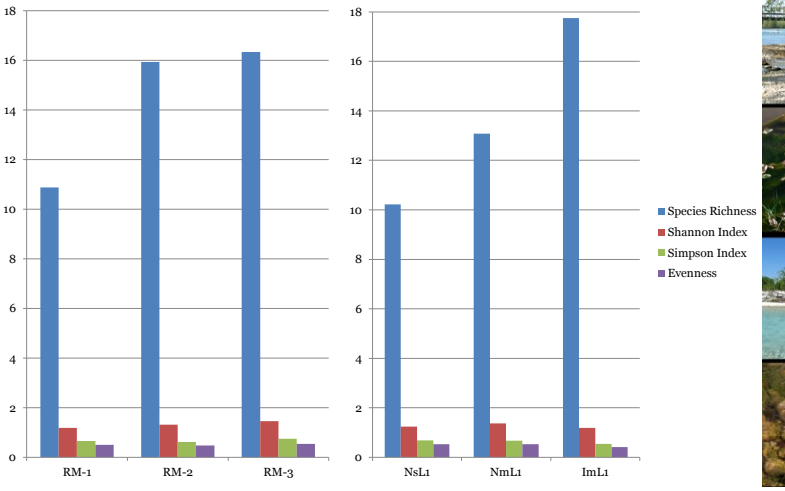
Geomorphological & Physicochemical Variables

VARIABLE	MEAN	MEDIAN	VARIANCE	RANGE	MIN	MAX
Altitude (m)	77	29	14760.2	759	-4	755
Catchment	1.68	2	0.41	2	1	3
Air temperature (°C)	16.15	16	3.5	8	12	20.0
Precipitation (mm)	643.33	700	67387.4	800	300	1100.0
Geomorphological type	1.44	1	0.551	3	1	4
Substrate channel	3.21	3	0.89	3	1	4
Channel width (m)	22.44	15	1811.7	248	2	250
Shading	1.72	1	1.12	4	1	5
Channel profile/ cross section alteration	2.60	3	0.74	3	1	4
Channel morphology	2.57	3	0.87	3	1	4
Local habitat alteration	2.70	3	0.60	3	1	4
Stream hydrology	2.45	3	0.84	3	1	4
Upstream dams influence	1.32	1	0.32	2	1	3
Water abstraction	2.31	2	0.68	3	1	4
Dykes (flood protection)	2.02	2	0.93	3	1	4
Water temperature (°C)	17.96	16.65	10.54	13.14	12.19	25.33
pH	7.61	7.815	1.33	9.3	6.06	9.3
DO (mg/l)	6.73	8.16	13.97	11.5	2.84	11.5
Conductivity (ms/cm)	0.46	0.46	0.05	1.57	0.12	1.57
Ammonium (mg/l)	0.19	0.03	0.33	3.17	0.001	3.17
Nitrate (mg/l)	3.73	0.87	40.58	30.34	0.007	30.35
Total Nitrogen (mg/l)	3.97	0.89	47.15	33.68	0.028	33.71
Ortho-phosphates (mg/l)	3.86	0.39	54.86	36.00	0.001	36
Land use	1.59	2	1.00	3	0	3
Urbanisation	1.11	1	0.10	1	1	2
Agriculture	2.53	3	0.91	3	1	4

Variables mean values-MEDGIG

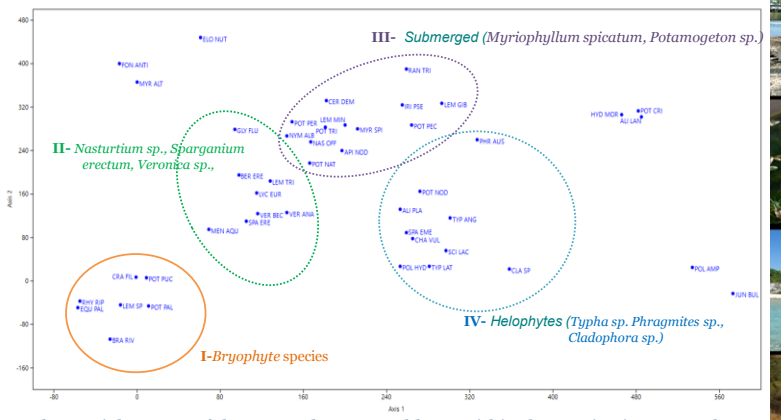


- Macrophyte mean values MEDGIG
- Macrophyte mean values NATIONAL

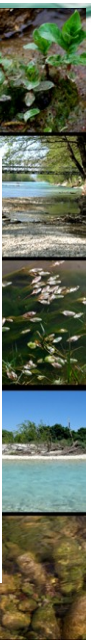


Monitoring Network- *spatial pattern of* ***macrophytes***

Detrended **C**orrespondence **A**nalysis (DCA)



The spatial pattern of the macrophyte assemblages within the monitoring network was analysed using Hierarchical cluster analysis (discr. level > 70%) while DCA was performed to visualize the spatial relationships between species & plant assemblages



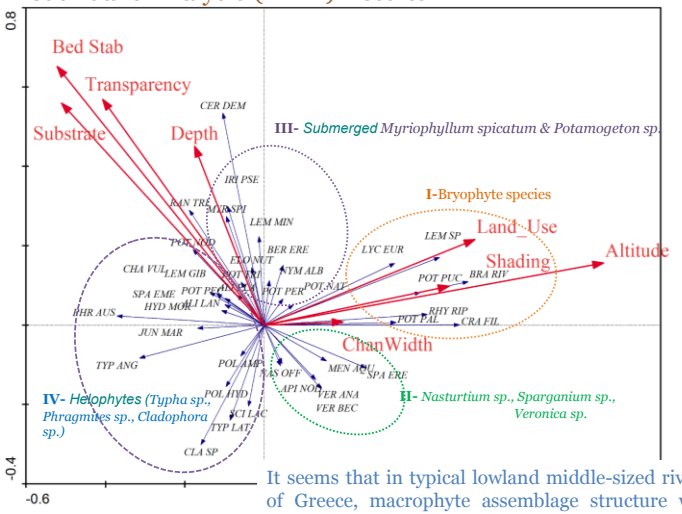
Monitoring Network - *spatial pattern of* ***macrophytes***

- **PERMANOVA** (permutational multivariate analysis of variance) pairwise tests to identify statistical differences among plant groups
- Results are presented as post-hoc test with p-values with **Bonferoni correction**

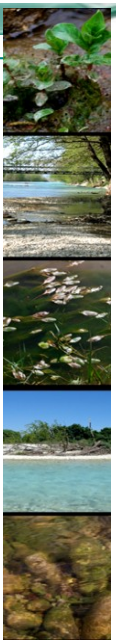
Groups	3	4	2	1
3		0.0006	0.0006	0.0012
4	0.0006		0.0018	0.0006
2	0.0006	0.0018		0.0468
1	0.0012	0.0006	0.0468	

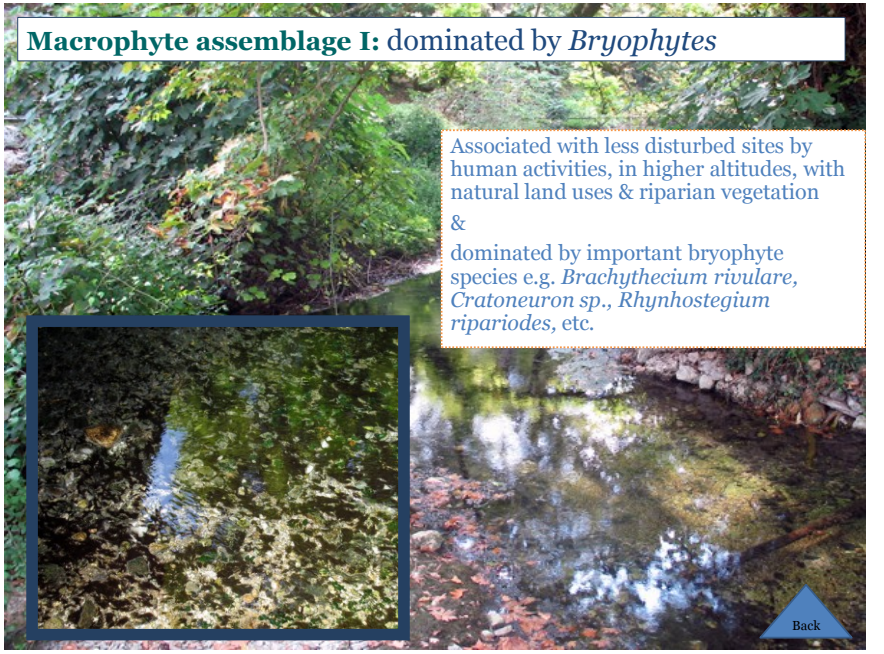
- ✓ Taxa primarily responsible for the differences between plant community types were identified with **Indicator Species Analysis**
- ✓ The results indicated that from 48 dominant aquatic macrophyte taxa are present in the monitoring network forming the 4 discrete clusters, **16** were **identify** as **Indicator Species**

Effects of Environmental variables on macrophytes structure - **R**edundant **A**nalysis (**RDA**) Results



It seems that in typical lowland middle-sized rivers of Greece, macrophyte assemblage structure was strongly associated with geomorphological features.



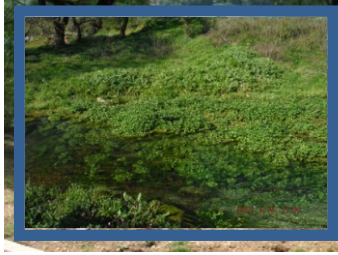


Macrophyte assemblage II- *Nasturtium officinale, Sparganiuum emersum, Veronica anagalis aquatica*

Dominated by *Nasturtium officinale, Sparganium emersum, Veronica anagalis aquatica, V. beccabunga, Glyceria fluitans*

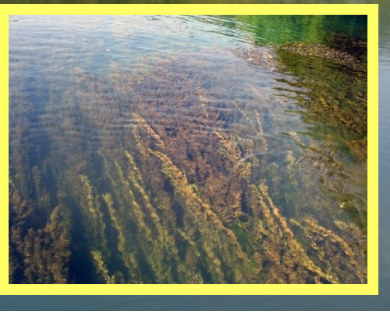
&

associated with high channel width, low depth & stable substrate



Macrophyte assemblage III- *Myriophyllum spicatum* & *Potamogeton* sp.

Dominates deeper waters with high transparency & unstable fine particulate organic matter.

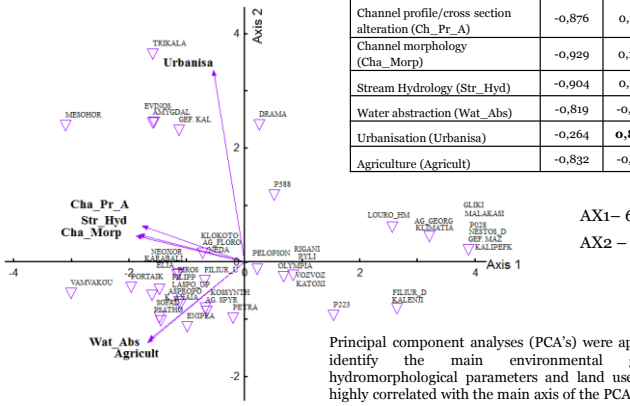


Macrophyte assemblage IV: Helophytes *Typha* sp., *Phragmites australis, Cladophora* sp.

Macrophyte assemblage IV dominated by helophyte species, *Typha* sp., *Phragmites australis, Scirpus* sp., *Polygonum* sp., *Cladophora* sp.

Found in lower altitudes with deep waters, absence of riparian zone

Pressure data analyses - PCA results



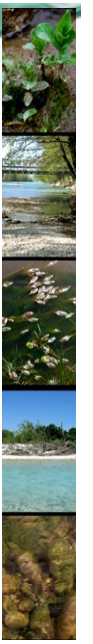
	AX1	AX2
Channel profile/cross section alteration (Ch_Pr_A)	-0,876	0,165
Channel morphology (Cha_Morp)	-0,929	0,120
Stream Hydrology (Str_Hyd)	-0,904	0,127
Water abstraction (Wat_Abs)	-0,819	-0,361
Urbanisation (Urbanisa)	-0,264	**0,883**
Agriculture (Agricult)	-0,832	-0,371

AX1– 64.65 %

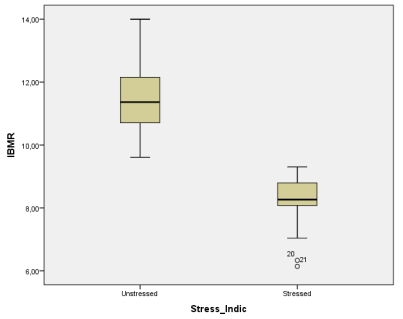
AX2 – 18.43 %

Principal component analyses (PCA's) were applied in order to identify the main environmental gradients. The hydromorphological parameters and land use categories were highly correlated with the main axis of the PCA and so they were used for the pressure gradient estimation.

PCA analysis showing the hydromorphological pressure gradient in surveyed rivers



IBMR and Pressure Gradient

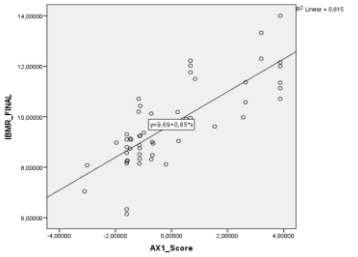


Box whisker plots showing the range of IBMR index in stressed and unstressed sites

The Macrophyte Biological Index for Rivers was estimated and after normalization, the class boundaries of IBMR were determined in a national level

IBMR & Pressure Gradient correlation

	Trophic metric	Correlation Coefficient-Spearman's rho	Sig. (2-tailed)
IBMR	T	-0.765	0.00

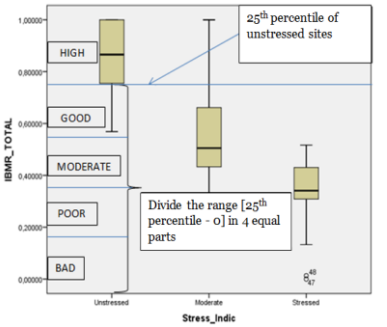


Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,784[a]	.615	.608	1.03139158

a. Predictors: (Constant), PC1_Score

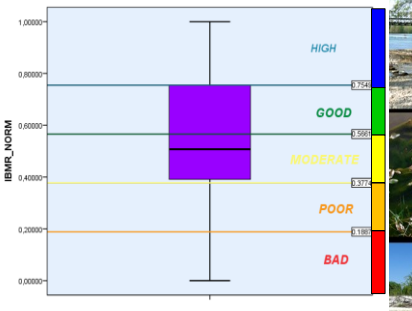
Regression analysis between IBMR index and pressure gradient

Setting class boundaries



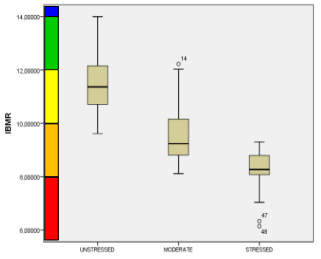
Calculation steps of numerical class boundary between the five ecological quality classes

Ecological classes

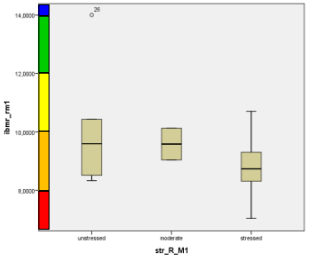


Box whisker plot showing the numerical class boundary between the five ecological quality classes

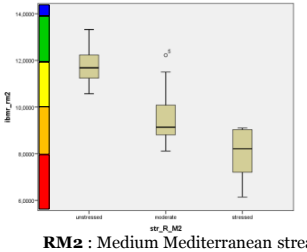
IBMR and Pressure Gradient (MEDGIG)



All Sites



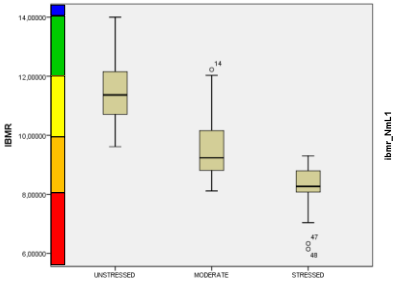
RM1 : Small Mediterranean streams



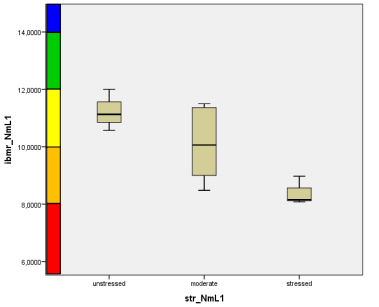
RM3 : Very few sites

RM2 : Medium Mediterranean streams

IBMR and Pressure Gradient (NATIONAL)



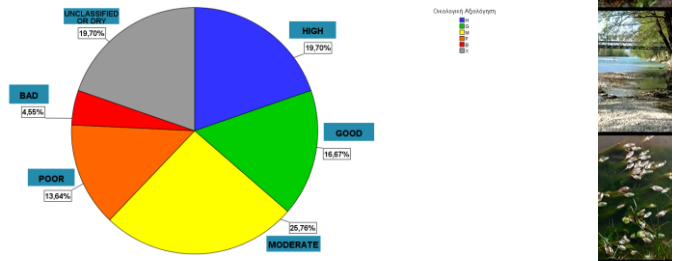
All Sites

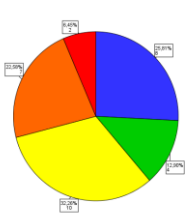


NmL1 : N : North GR
m : Medium runoff
L : Low altitude
1 : Fast flow

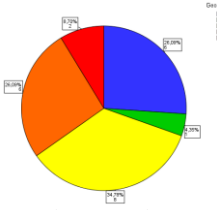
Assessment of Biological Quality (Summer 2014)

All Sites

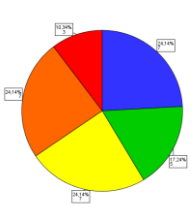




RM2- Sites



Ionian GR- Sites



North GR- Sites