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INTEGRATED PHYTOPLANKTON INDEX (IBI-PH) – A DESIGN FOR ECOLOGICAL/ENVIRONMENT QUALITY ASSESSMENT

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PROBLEM and CHALLENGES

Marine phytoplankton play a key role in the lower food web and transfer of energy to maintain the function and productivity at the level of a healthy ecosystem. Community state is a function of a multiple suit of biotic and abiotic interactions that precondition its integrated growth environment. As a fast response component of the marine biota phytoplankton is a valuable indicator of the ecological/environmental status Biological quality element *sensu* WFD and component of several MSFD Descriptors).

Among the main challenges in the implementation of WFD and MSFD is the growing demand for robust and reliable methodological approaches in selecting indicators for diagnose of the ecological state taking into account the complexity of multifactor drivers/pressures interactions and phytoplankton responses that are likely non-linear, species and region specific and time dependant.

Main difficulties:

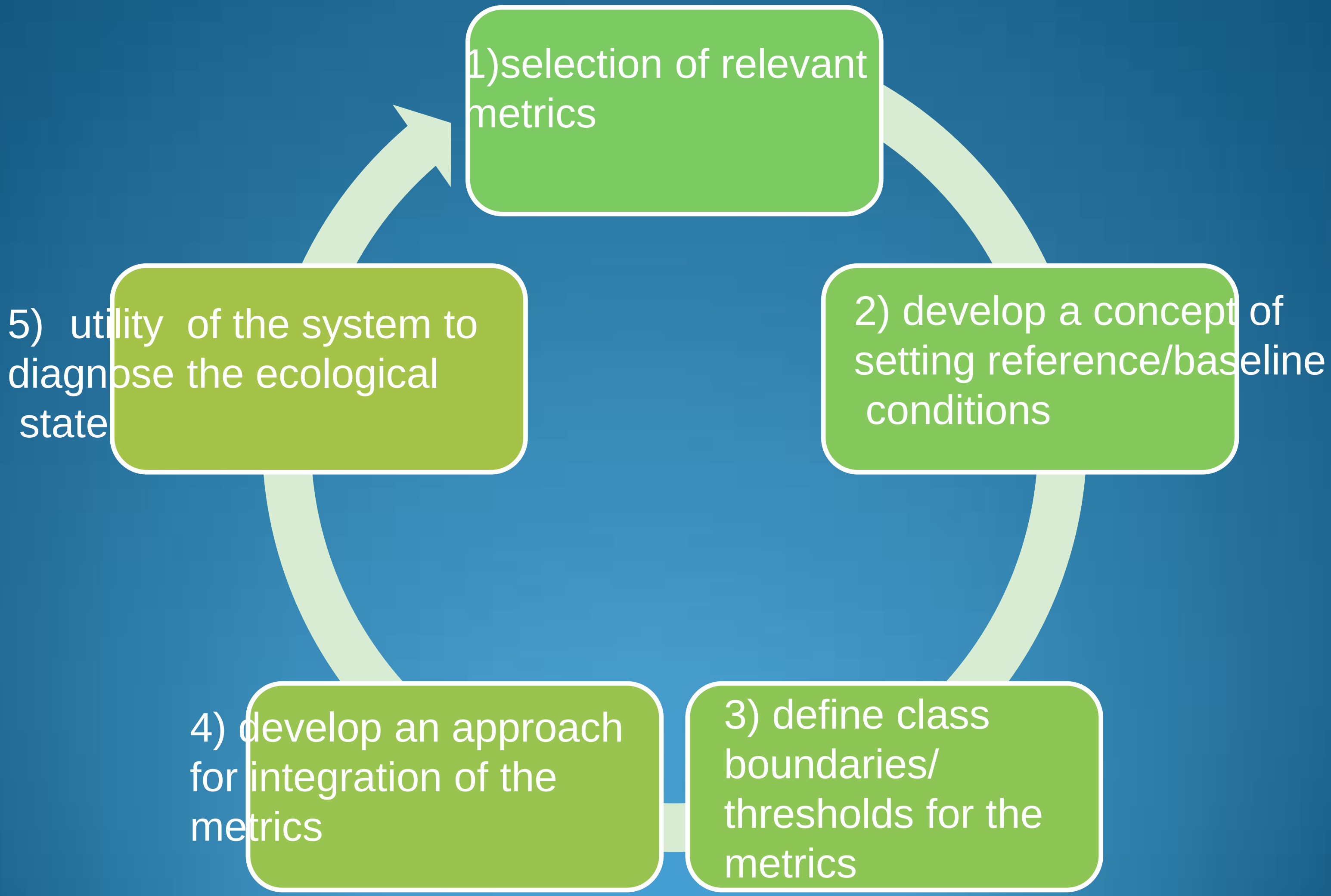
- the species diversity and community composition manifest high spatio-temporal variability as an inhereted natural feature
- lack of unique (engineer) species which presence or growth could be used as an universal indicator
- lack of unique community of species specific features that could diagnose a typical ecological state of the environment

AIM

Design a composite Integrated Phytoplankton Index (IBI-PH) to integrate a suit of phytoplankton community traits conceived to capture different aspects of phytoplankton reaction to the marine environment conditions

APROACH

The approach integrates the following steps:



SELECTION OF RELEVANT METRICS

Quantitative metrics

- Total abundance [cells/l]
- Total biomass [mg/m3]
- Chlorophyll a [mg/m3]

Nonparametric biodiversity indices

Menhinick (1964)

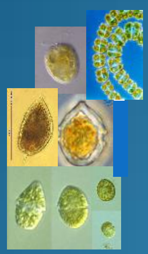
$D = S/\sqrt{N}$ и

Sheldon (1969)(Spatharis, Tsirtis, 2010)

$E = \exp(H')/S$

Taxonomic based metrics

DE%



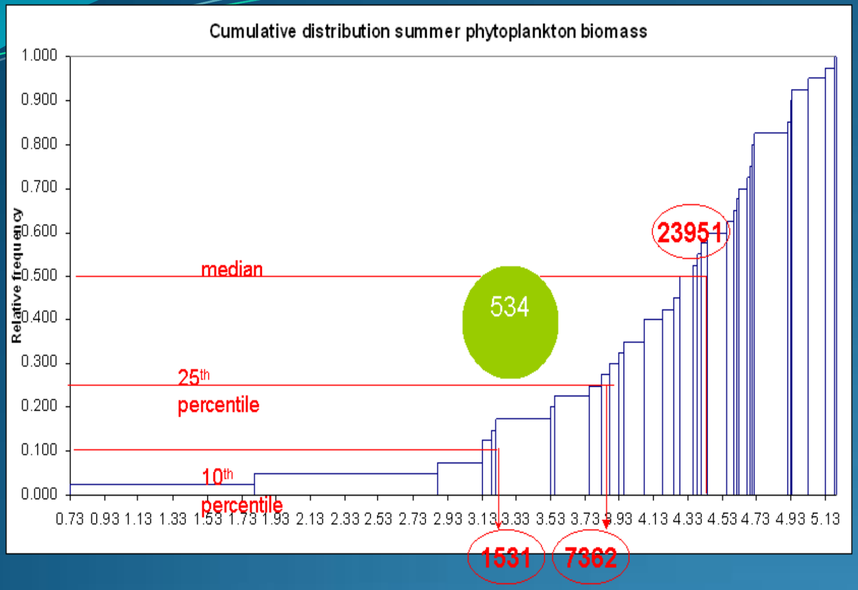
A number of dinoflagellate C-strategy species abundance *Heterocapsa rotundata, Heterocapsa triquetra, Scrippsiella trochoidea, Prorocentrum minimum, Prorocentrum micans and Gymnodinium/Gyrodinium* as a % of the Total dinoflgellates abundance [DE%]

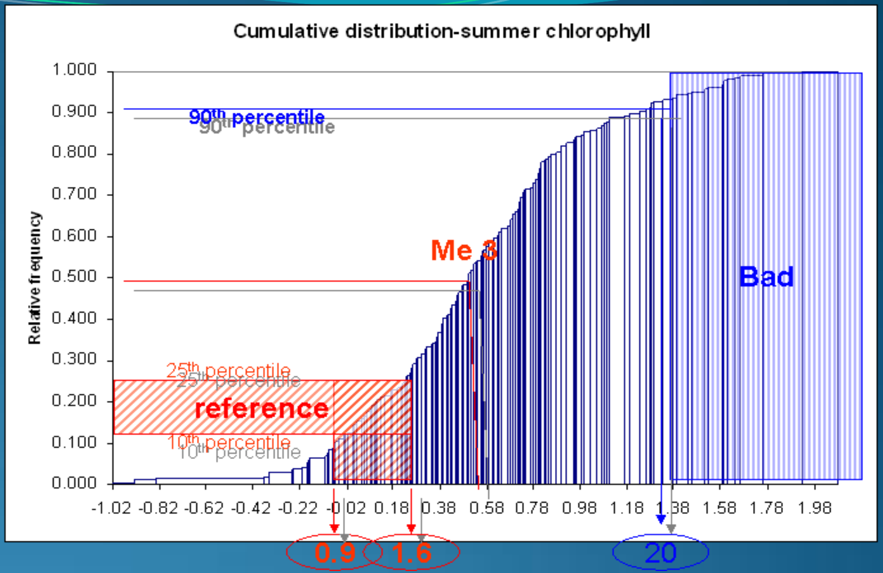
MEC%

Sum of the abundance of microflagellates + Euglenophyceae + Cyanophyceae as a % from the total abundance of the phytoplankton community in summer

BAC:DIN - Diatoms:Dinoflagellates spring biomass ratio (in spring) widely used in the Black Sea as an indication of eutrophication related shifts in phytoplankton taxonomic structure

CONCEPT OF SETTING REFERENCE/BASELINE CONDITIONS





The approach for the identification of reference conditions is based on:

✓historical data from the relatively pristine period of the Bulgarian Black Sea coast (1954-1970 – published seasonal data);

✓10 percentile (lower quartile) of a long-term data set (period 1983-2005) to test applicability for definition of reference values and for the selection of “bad values” (from the period of intensive anthropogenic eutrophication – the 80-ies).

This step was crucial for the identification of reference values for chlorophyll a. Due to lack of chlorophyll a measurements from the reference period and before 1990, the 10 percentile from a long-term data set (1990-2006) was determined and its applicability tested against the results from the analysis of the phytoplankton data set.

DEFINE CLASSBOUNDARIES

The central definition of the quality classes boundaries is given by the value of Accepted Deviation (AcDev) from the reference condition (RefCon). The EQR is equal to 1.00 if Accepted status is better than or equal to RefCon and approaches 0.00 as deviation from RefCon becomes large.

The RefCon for the metrics Phytoplankton Numerical abundance [cells/l], Total Biomass [mg/m3], chlorophyll a [µg/l], MEC% and DE% are derived from historical data from the relatively reference period of the Black Sea The lower value for “bad” status is derived from the data set during the severe eutrophication period of the Black Sea, thus the RefCon and the BadCon are fixed values.

The EQR boundary between High and Reference status is always set equal to 0.95. Thus, this permissible deviation from the RefCon (5%) represents a generic estimate of the uncertainty margin for all indicators.

For good status we assume an acceptable deviation from the High value (0,95) equal to 16%, thus the EQR H/G is set to 0.8 with a suggested fixed value. We also assume that the lowest bad is an acceptable deviation from the High not higher than 76% e.g. the boundary EQR Poor/Bad is set to 0.23 and that the acceptable deviation for good status is lower than 50% from the High.

For the taxonomic related Metrics MEC% and DE% the approach is the same but we accept equidistant deviations at 0.2 for H/G and 0.75 for P/B

CLASSBOUNDARIES

For the Diversity indices we follow the classification system of (Spatharis & Tsirtsis, 2010) and equidistant deviations at 0.2 for H/G and 0.75 for P/B

Biodiversity Metric	High	Good	Moderate	Poor	Bad
Index Menhinick (1964)	0.19 - 0.15	0.15 - 0.09	0.09 - 0.05	0.05 - 0.03	0.03 - 0.01
EQR	1.0 - 0.75	0.75 - 0.55	0.55 - 0.35	0.35 - 0.25	0.25 - 0
EQR norm	1 - 0.80	0.80 - 0.63	0.63 - 0.43	0.43 - 0.23	0.23 - 0.0

Biodiversity Metric	High	Good	Moderate	Poor	Bad
Index Sheldon (1969)	0.96 - 0.78	0.77 - 0.49	0.48 - 0.32	0.31 - 0.21	0.20 - 0.09
EQR	1 - 0.75	0.75 - 0.55	0.55 - 0.35	0.35 - 0.25	
EQR norm	1 - 0.80	0.80 - 0.63	0.63 - 0.43	0.43 - 0.23	0.23 - 0.0

Taxonomic metric	High	Good	Moderate	Poor	Bad
Microflagellates, Euglenophyceae, Cyanophyceae (MEC) - % total phytoplankton abundance	2(5) - 20	20 - 35	35 - 55	56 - 75	>75
EQR	1 - 0.80	0.8 - 0.65	0.65 - 0.45	0.45 - 0.25	>0.25
EQR norm	1 - 0.80	0.80 - 0.63	0.63 - 0.43	0.43 - 0.23	0.23 - 0.0

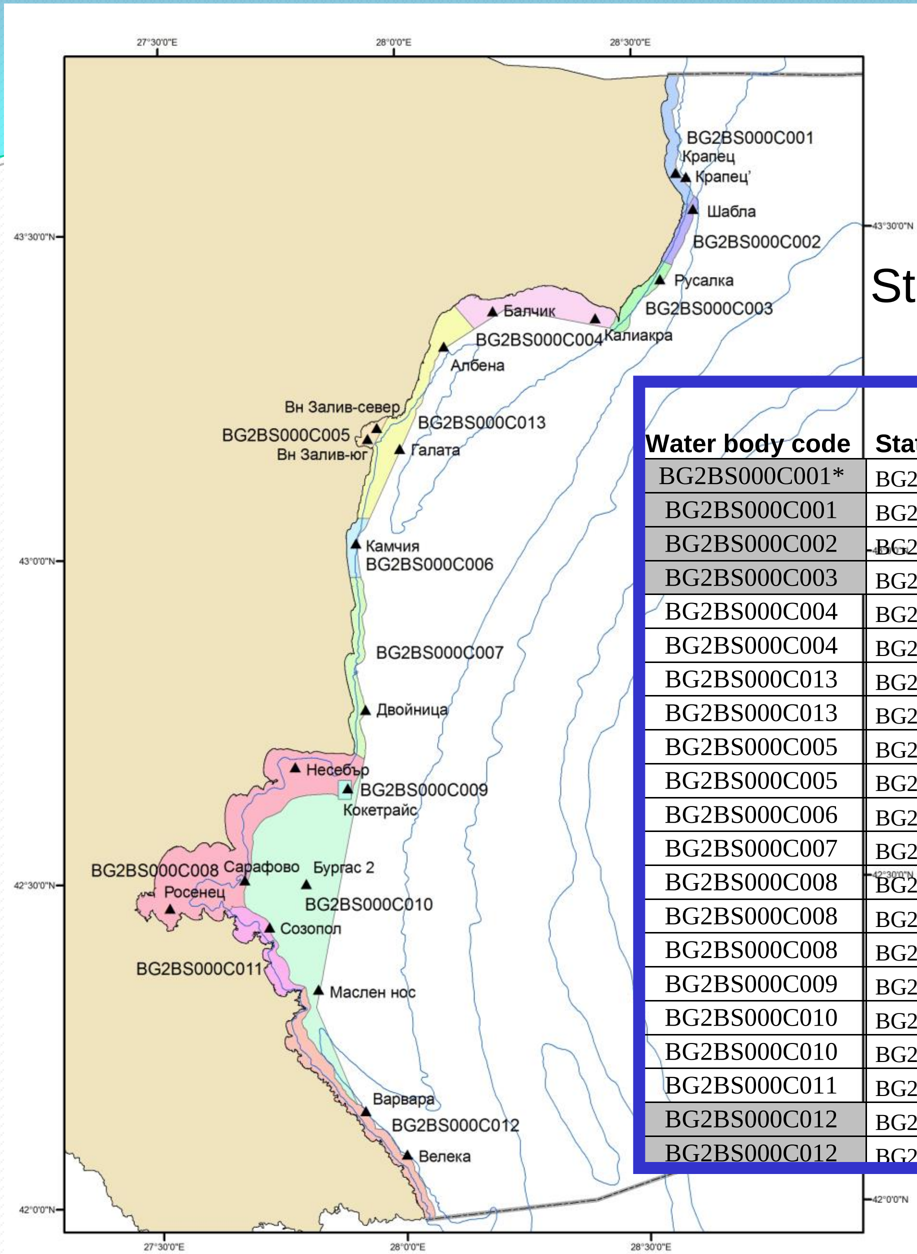
Taxonomic metric	High	Good	Moderate	Poor	Bad
DE - % total phytoplankton abundance *Heterocapsa rotundata, Heterocapsa triquetra, Scrippsiella trochoidea, Prorocentrum minimum, Prorocentrum micans* and *Gymnodinium/Gyrodinium (C- strategy species -% of the total abundance of Dinoflagellates)*	2(5) - 20	20 - 35	35 - 55	56 - 75	>75
EQR	0.95 - 0.76	0.8 - 0.65	0.65 - 0.45	0.45 - 0.25	>0.25
EQR norm	1 - 0.80	0.80 - 0.63	0.63 - 0.43	0.43 - 0.23	0.23 - 0.0

	Summer				
Biomass Metric	High	Good	Moderate	Poor	Bad
Biomass (mg/m^3)	400 - 700	701 - 950	951 - 2500	2501 – 5000	>5000
EQR	1 - 0.8	0.8 - 0.63	0.63 - 0.43	0.43 - 0.23	>0.23
EQRnorm	1 - 0.80	0.80 - 0.63	0.63 - 0.43	0.43 - 0.23	0.23 - 0.0

	Summer				
Abundance Metric	High	Good	Moderate	Poor	Bad
Total abundance (10^3 cells/l)	400 - 500	501 - 800	801 - 1500	1501 - 3000	>3000
EQR	1 - 0.8	0.8 - 0.63	0.63 - 0.43	0.43 - 0.23	>0.23
EQRnorm	1 - 0.80	0.80 - 0.63	0.63 - 0.43	0.43 - 0.23	0.23 - 0.0

	Summer				
Chlorophyll a Metric	High	Good	Moderate	Poor	Bad
Chl a, μg/l	< 1.5	1.5 – 2.05	2.05 – 3.19	3.19 – 7.10	> 7.10
EQR	1 - 0.80	0.80 – 0.67	0.67 – 0.43	0.43 - 0.19	> 0.19
EQRnorm	1 -0.80	0.80 - 0.63	0.63 - 0.43	0.43 - 0.23	0.23 - 0.0

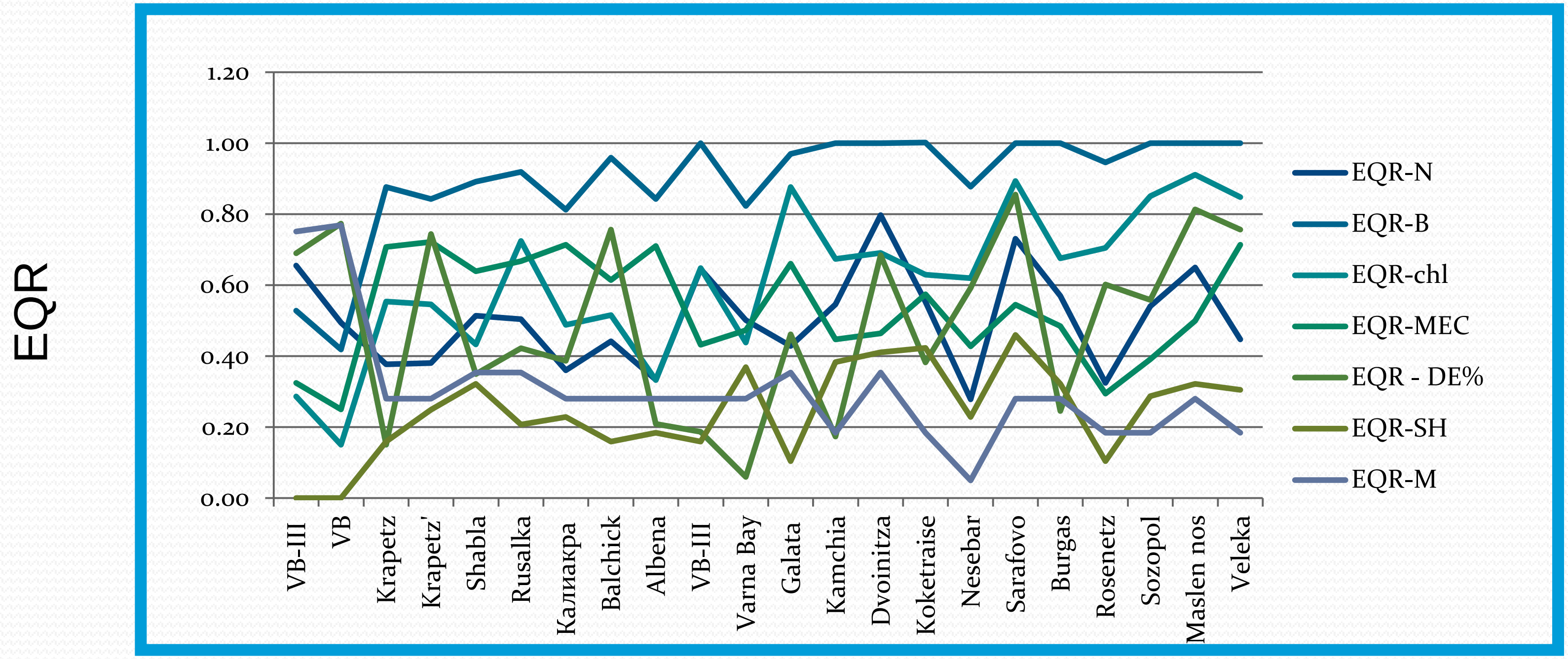
Stations codes, coordinates and depths



Water body code	Station code	Station name	latitude	Longitude	Depth,m
BG2BS000C001*	BG2BS00000MS001	Krapetz	43°35.250'N	28°35.500'E	16
BG2BS000C001	BG2BS00000MS101	Krpetz'	43°34.866'N	28°36.788'E	22
BG2BS000C002	BG2BS00000MS102	Shabla	43°32.000'N	28°36.400'E	37
BG2BS000C003	BG2BS00000MS002	Rusalka	43°25.460'N	28°33.202'E	27
BG2BS000C004	BG2BS00000MS003	Kaliakra	43°22.000'N	28°25.000'E	16
BG2BS000C004	BG2BS00000MS104	Balchik	43°22.750'N	28°12.000'E	17
BG2BS000C013	BG2BS00000MS105	Albena	43°19.500'N	28°05.800'E	17
BG2BS000C013	BG2BS00000MS004	Galata	43°10.000'N	28°00.000'E	24
BG2BS000C005	BG2BS00000MS005	Varna bay-Notrh	43°12.100'N	27°57.300'E	17
BG2BS000C005	BG2BS00000MS006	Varna Bay South	43°11.100'N	27°56.200'E	15
BG2BS000C006	BG2BS00000MS007	Kamchia	43°01.500'N	27°54.550'E	19
BG2BS000C007	BG2BS00000MS008	Dvoinitza	42°46.100'N	27°55.560'E	30
BG2BS000C008	BG2BS00000MS009	Nesebar	42°40.800'N	27°46.700'E	22
BG2BS000C008	BG2BS00000MS010	Sarafovo	42°30.380'N	27°40.330'E	28
BG2BS000C008	BG2BS00000MS011	Rosenetz	42°27.800'N	27°31.000'E	15
BG2BS000C009	BG2BS00000MS109	Koketraiz	42°38.800'N	27°53.200'E	19
BG2BS000C010	BG2BS00000MS012	Burgas Bay	42°30.019'N	27°48.000'E	36
BG2BS000C010	BG2BS00000MS110	Cape maslen	42°20.170'N	27°49.150'E	47
BG2BS000C011	BG2BS00000MS111	Sozopol	42°26.000'N	27°43.350'E	38
BG2BS000C012	BG2BS00000MS112	Varvara	42°09.000'N	27°54.750'E	47
BG2BS000C012	BG2BS00000MS113	Veleka	42°05.000'N	28°00.000'E	53

Map of WB and monitoring stations WFD

ASSESSMENTS BY DIFFERENT METRICS



N [cells/l], B [mg/m3], Chl[mg/m3], MEC%; DE%, SH, M - Indices

APPROACH FOR INTEGRATION OF THE METRICS

We apply the combination rule of metrics assuming equal weight (1) (average metric scores) proposed by Spatharis S., G. Tsirtsis (2010) into

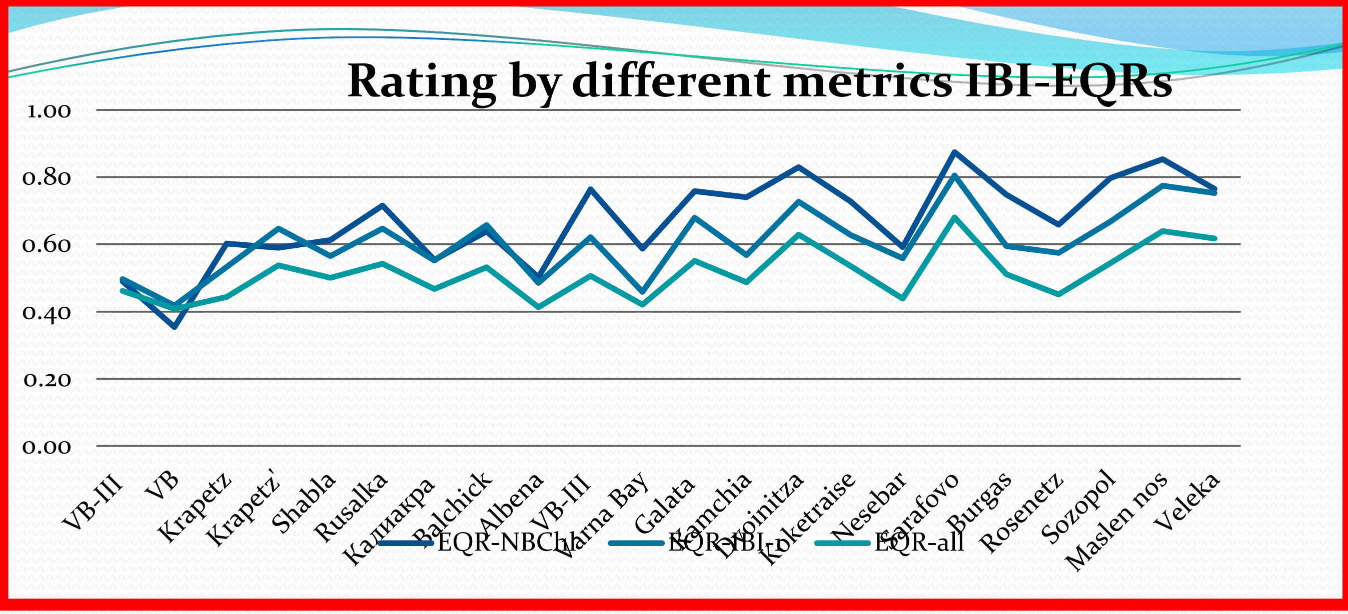
Integrated Biological Index (IBI-Ph) = arithmetic average of EQRs for the single metrics, after normalization of the EQRs boundaries

The EQRs for the Integrated Biological Index are calculated as simple arithmetic average of the EQRs for each quality class, since these ratios are standardized in the 0–1 range

EQR IBI: H/G -0.8; G/M – 0.63 ; M/P – 0.43 and P/B – 0.23

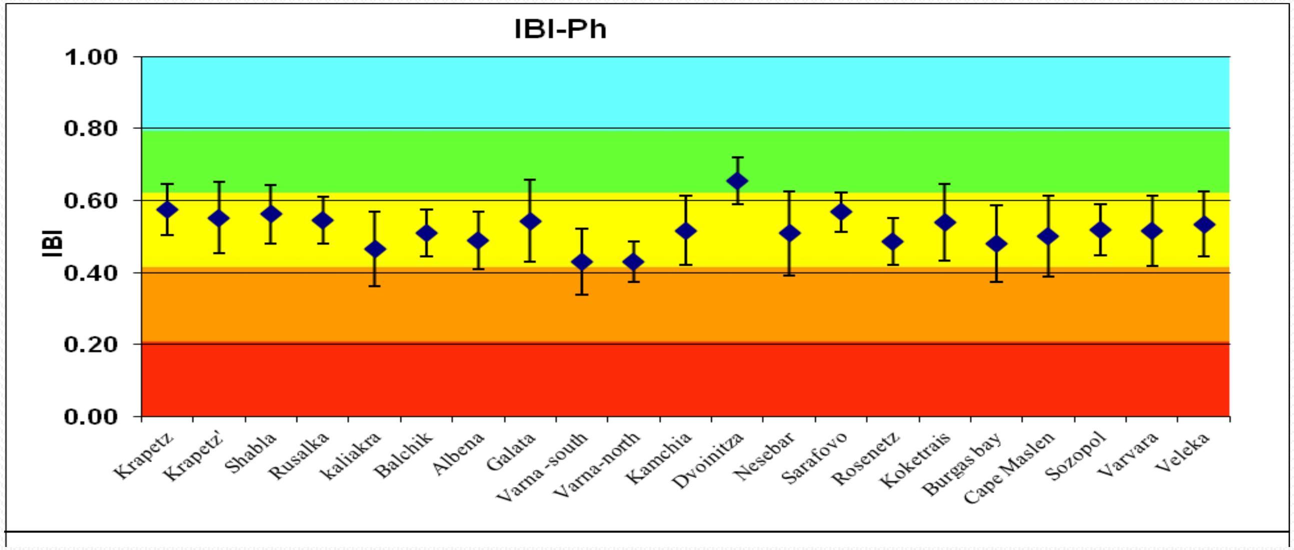
The difference with Spatharis S., G. Tsirtsis (2010) is in the metrics that were integrated: phytoplankton abundance, chlorophyl a and Menhinik index

EQR

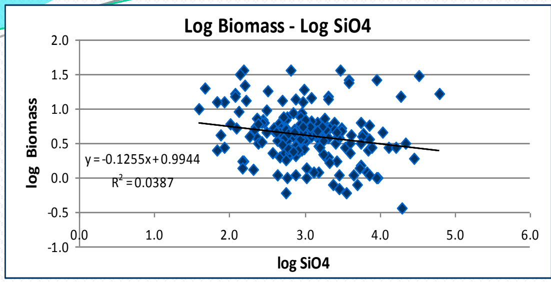


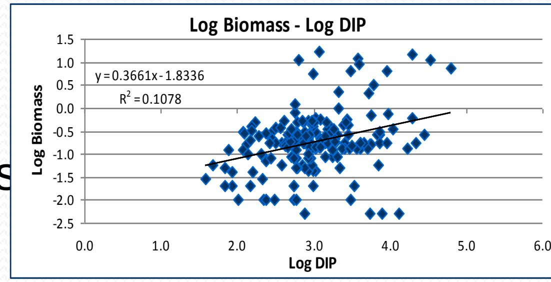
EQR NBChl (quantitative); EQR-IBI-1 (Q+taxonomic based); EQR- all

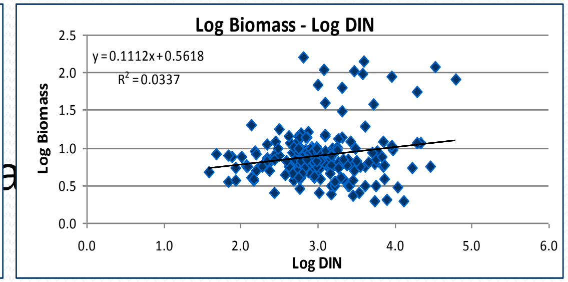
EQR



UTILITY FOR DIAGNOSE





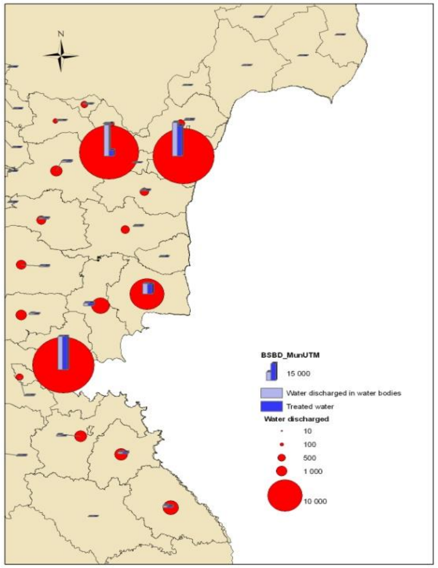


Statistical summaries of correlation coefficients (in red statistical significant at $p < .050$)

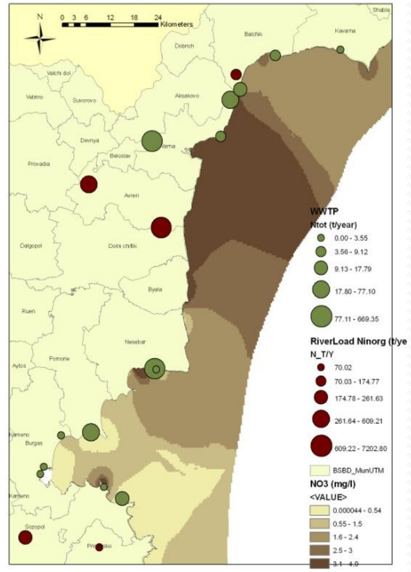
	N[cells/l]	B [mg/m3]	MEC%	DE%	Chl [mg/m3]	ERQ - N [cells/l]	EQR - B [mg/m3]	EQR MEC%	EQR DE%	EQR Chl	EQR-IBI	PO4 (uM)	NO3 (uM)	DIN (uM)	SiO4(uM)
N[cells/l]															
B [mg/m3]	0.808882														
MEC%	-0.141634	-0.491851													
DE%	-0.042570	0.261452	-0.345594												
Chl [mg/m3]	0.561149	0.697774	-0.279491	0.174007											
ERQ- N	-0.778528	-0.303017	-0.265009	0.395491	-0.221649										
EQR-B	-0.605861	-0.877653	0.597583	-0.305740	-0.644558	0.115750									
EQR-Mec%	0.154287	0.499253	-0.999725	0.347739	0.281369	0.254532	-0.605192								
EQR - DE%	0.043860	-0.260135	0.345605	-0.999997	-0.172540	-0.396512	0.304180	-0.347735							
EQR-Chl	-0.482906	-0.621105	0.212431	-0.111828	-0.976173	0.196200	0.545025	-0.213620	0.110451						
EQR-IBI	-0.767311	-0.785052	0.062860	-0.136492	-0.864815	0.517127	0.649808	-0.068890	0.134681	0.855481					
PO4 (uM)	0.737192	0.567925	0.115263	0.462427	0.442422	-0.573514	-0.407384	-0.102768	-0.461247	-0.362007	-0.693515				
NO3 (uM)	0.438068	0.506797	0.251877	0.313382	0.594303	-0.184312	-0.373833	-0.248908	-0.312000	-0.601992	-0.753763	0.652639			
DIN (uM)	0.768151	0.869983	-0.298395	0.287373	0.701696	-0.289848	-0.696091	0.306559	-0.286188	-0.647425	-0.773019	0.645538	0.743427		
SiO4(uM)	0.238602	-0.312473	0.725209	-0.179954	-0.235225	-0.626987	0.451836	-0.717200	0.179927	0.241686	-0.019034	0.471177	0.169971	-0.078579	
S (psu)	-0.264991	-0.596042	0.648247	-0.149808	-0.495868	-0.146755	0.548814	-0.644547	0.149196	0.506305	0.403280	0.010905	-0.364933	-0.668099	0.587127

Metric	Pressure	n	r2
EQR-IBI	TRIX	45	0.31
EQR-DE	TRIX	45	0.06
EQR-IBI	PO4	66	0.18
EQR-IBI	NO3	66	0.04
EQR-IBI	DIN	66	0.03
B[mg/m3]	PO4	66	0.07
B[mg/m3]	NO3	66	0.05
B[mg/m3]	DIN	66	0.05
MEC%	N/P	66	0.03
DE%	N/P	66	0.04
EQR-MEC	PO4	66	0.04
EQR-MEC	NO3	66	0.01
DE%	PO4	66	0.12
DE%	NO3	66	0.11
EQR-DE	PO4	66	0.12
EQR-DE	NO3	66	0.11
DE%	TRIX	45	0.54
Sheldon	TRIX	45	0.15

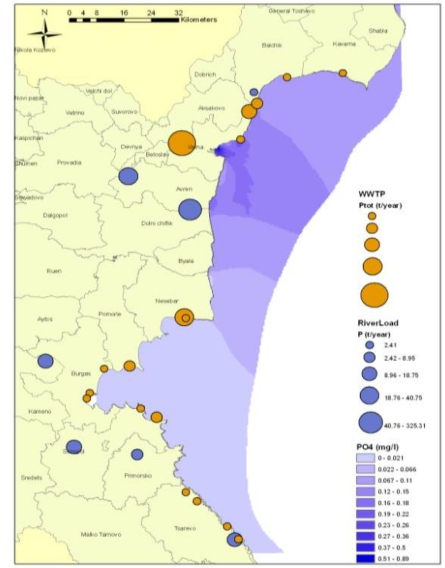
St_Code	N[cells/l]	B [mg/m3]	MEC%	DE%	Chl [mg/m3]	EQR N cells/l	EQR B(mg/m3)	EQR Mec%	EQR DE%	EQR Chl [mg/m3]	EQR EQR-IBI	PO4 (uM)	NO3 (uM)	DIN (NOx+NH 4)	SiO4 (uM)	S (psu)
Krapetz	1574694	546.67	19.20	66.42	2.08	0.51	0.99	0.82	0.33	0.66	0.59	1.56	0.85	0.85	17.33	17.50
Balchick	1489661	336.17	37.40	23.60	2.95	0.52	1.00	0.63	0.77	0.54	0.57	0.17	4.55	4.55	16.73	16.50
VG	544113	1285.58	14.71	66.56	1.55	0.91	0.76	0.86	0.33	0.77	0.68	0.25	0.61	0.61	5.58	17.41
VB-III	760495	1649.35	30.03	65.54	5.59	0.84	0.98	0.70	0.34	0.30	0.51	0.79	7.16	7.16	7.03	16.34
VB	1262638	2469.16	21.91	72.72	8.17	0.71	0.65	0.79	0.27	0.17	0.39	1.54	9.86	9.86	8.04	15.61
Kamchia	682994	320.29	34.37	84.87	2.17	0.82	1.00	0.66	0.14	0.65	0.59	1.74	9.32	9.32	19.11	16.70



Water discharge

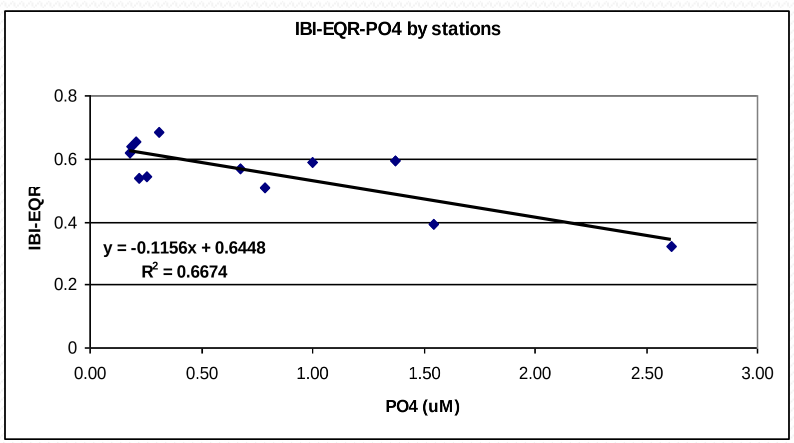


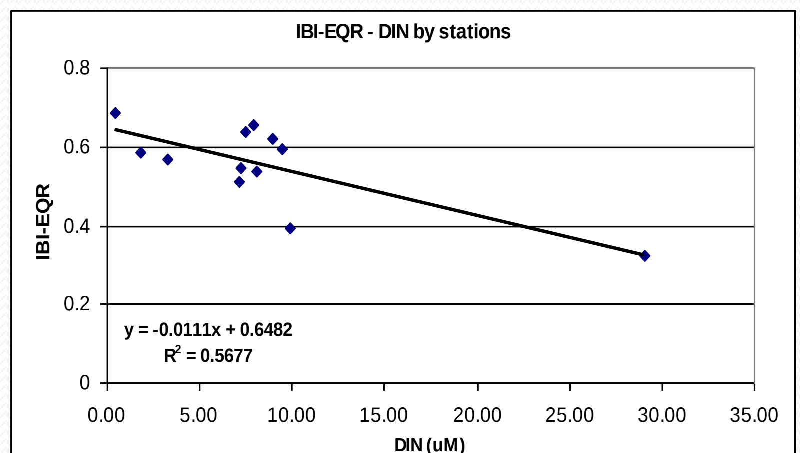
N input



P input

Maps of averaged land –based pressures along the Bulgarian Black Sea coast



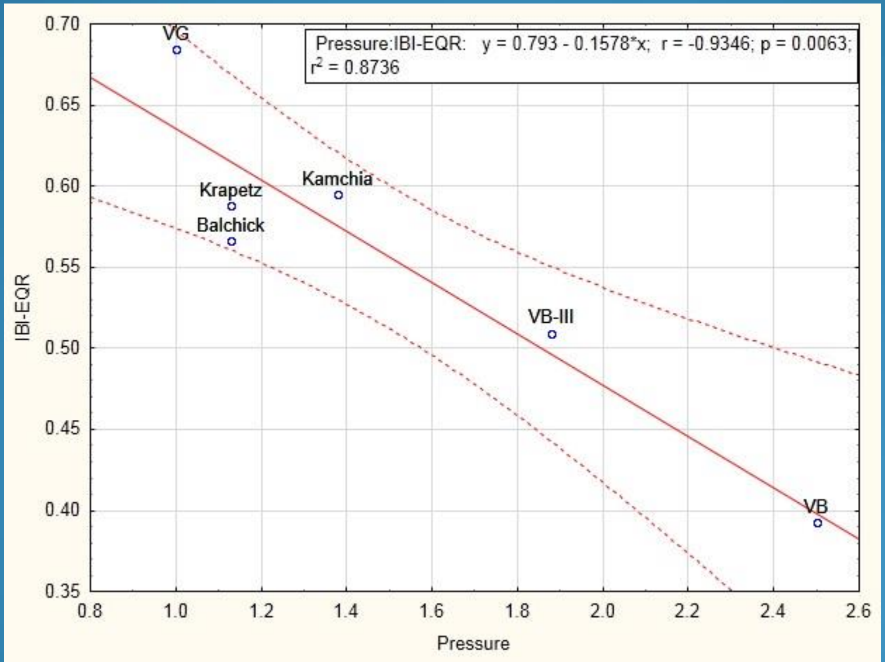


Pressure	Proxy
Agricultural diffuse inputs	Agricultural area as % from the 1.5 km coastal land Number of stocks breeding farms and domestic animals per water body for the year and data of fertilizers or nutrients from diffuse sources
Danube River input	Average annual discharge and total N and P loads [t/y] for 2007-2010 of major rivers
Domestic discharges (nutrients)	WWTP‘s discharge and nutrient N & P annual loads [t/y] for the period 2000-2010
Organic loads (BOD5)	WWTP ‘s discharge and annual loads of BOD5 [t/y]
Urbanization	Number of population and % of urban area in the 1.5 km coastal for the water body
Tourism (nutrients)	Number of arrivals and nights spent for the resorts
Port activity	Data of ship inspections for Burgas and Varna ports

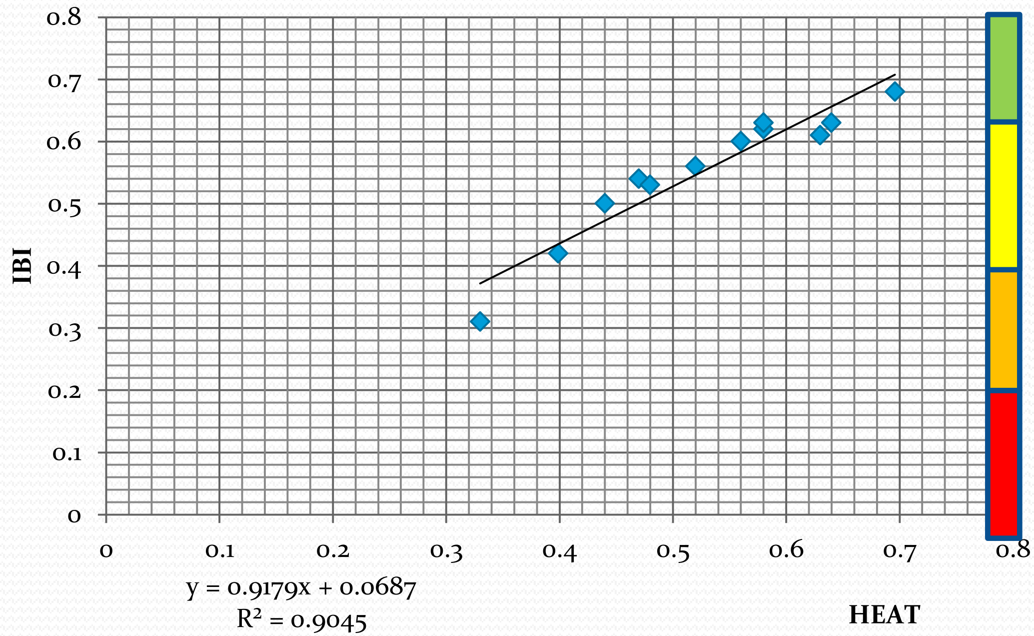
Pressure scoring and EQR – IBI by stations (after normalisation)

pressure score: 1-low pressure ; 2-moderate pressure ; 3-high pressure

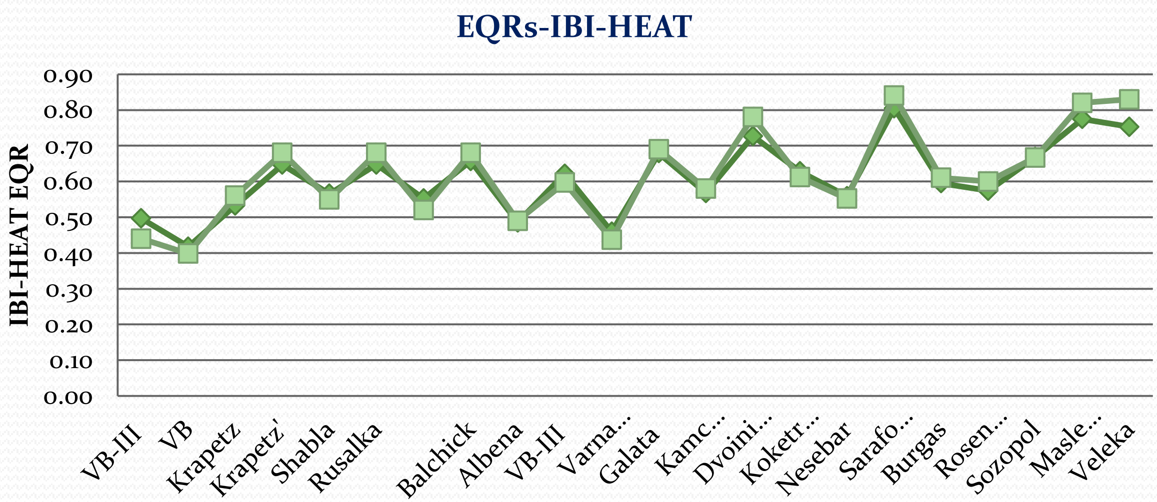
Station Name	Agricultural diffuse inputs	River discharge	Domestic discharges/WWTP (nutrients)	Industrial discharges	Organic loads (BOD5)	Urbanization	Tourism (nutrients)	Port activity	TOTAL PRES-SURES	Pres-sure Index	EQR-IBI	Class
Krapetz	2	1	2	0	2	1	1	0	9	1.13	0.59	Moderate
Balchick	1	0	1	1	1	1	3	1	9	1.13	0.57	Moderate
VG	0	0	1	1	1	1.5	1.5	2	8	1.00	0.68	Good
VB-III	0	0	3	2	3	3	3	1	15	1.88	0.51	Moderate
VB	2	0	3	3	3	3	3	3	20	2.50	0.39	Poor
Kamchia	3	3	1	0	2	1	1	0	11	1.38	0.59	Moderate



COMPARISON HEAT TOOL (HELCOM) – IBI-PH



HEAT	IBI
0.58	0.62
0.33	0.31
0.47	0.54
0.58	0.63
0.48	0.53
0.64	0.63
0.63	0.61
0.52	0.56
0.70	0.68
0.44	0.5
0.40	0.42
0.56	0.6



CONCLUDING REMARKS

The application of of synthetic index - IBI-PH seems to be advantageous for the assessment of coastal water quality as compared to the application of single metrics

However the functional relationships does not hold on case by case setting

Method for weighting the indicators might be considered and examined as not all metric may have equal sensitivity to the anthropogenic pressures

Synoptic data including pressures of regular measurements with a frequency matching the temporal variation in the assessment sites are crucial in order to improve our undestanding and validate the classification system

How do we account for lack of scientific understanding and unpredictable change to be able to replace statistical with ecological assessment

Thank you for your attention

GES ???