NACIONALNI INŠTITUT ZA BIOLOGIJO
MORSKA BIOLOŠKA POSTAJA

VPLIV ANTROPOGENIH DEJAVNIKOV IN KLIMATSKIH SPREMEMB NA MORSKE MIKROORGANIZME

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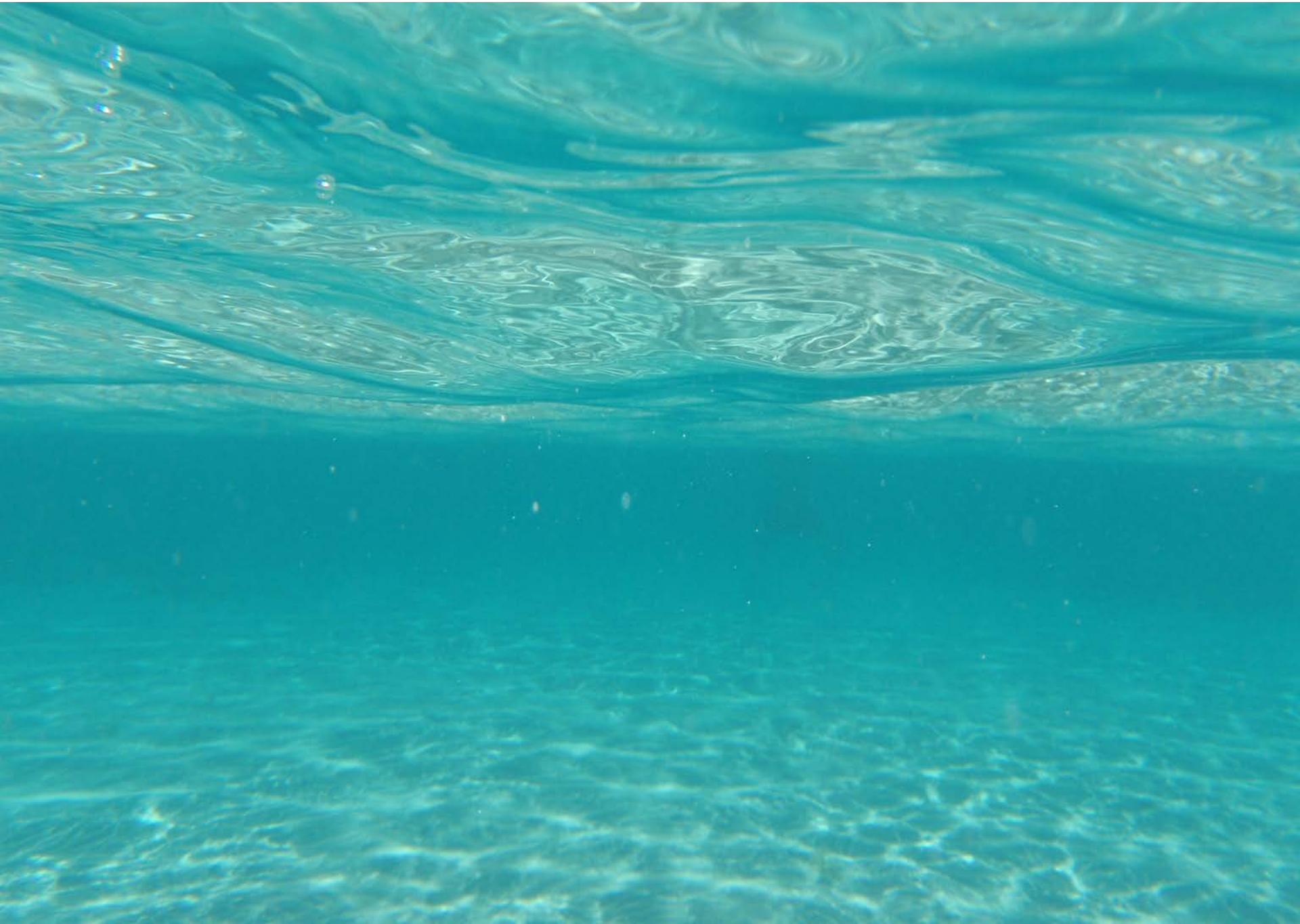
environmental microbiology

society for applied microbiology sfam

Environmental Microbiology (2014) doi:10.1111/1462-2920.12519

Bacterial community shift is induced by dynamic environmental parameters in a changing coastal ecosystem (northern Adriatic, northeastern Mediterranean Sea) – a 2-year time-series study

MIKROORGANIZMI V MORSKEM EKOSISTEMU



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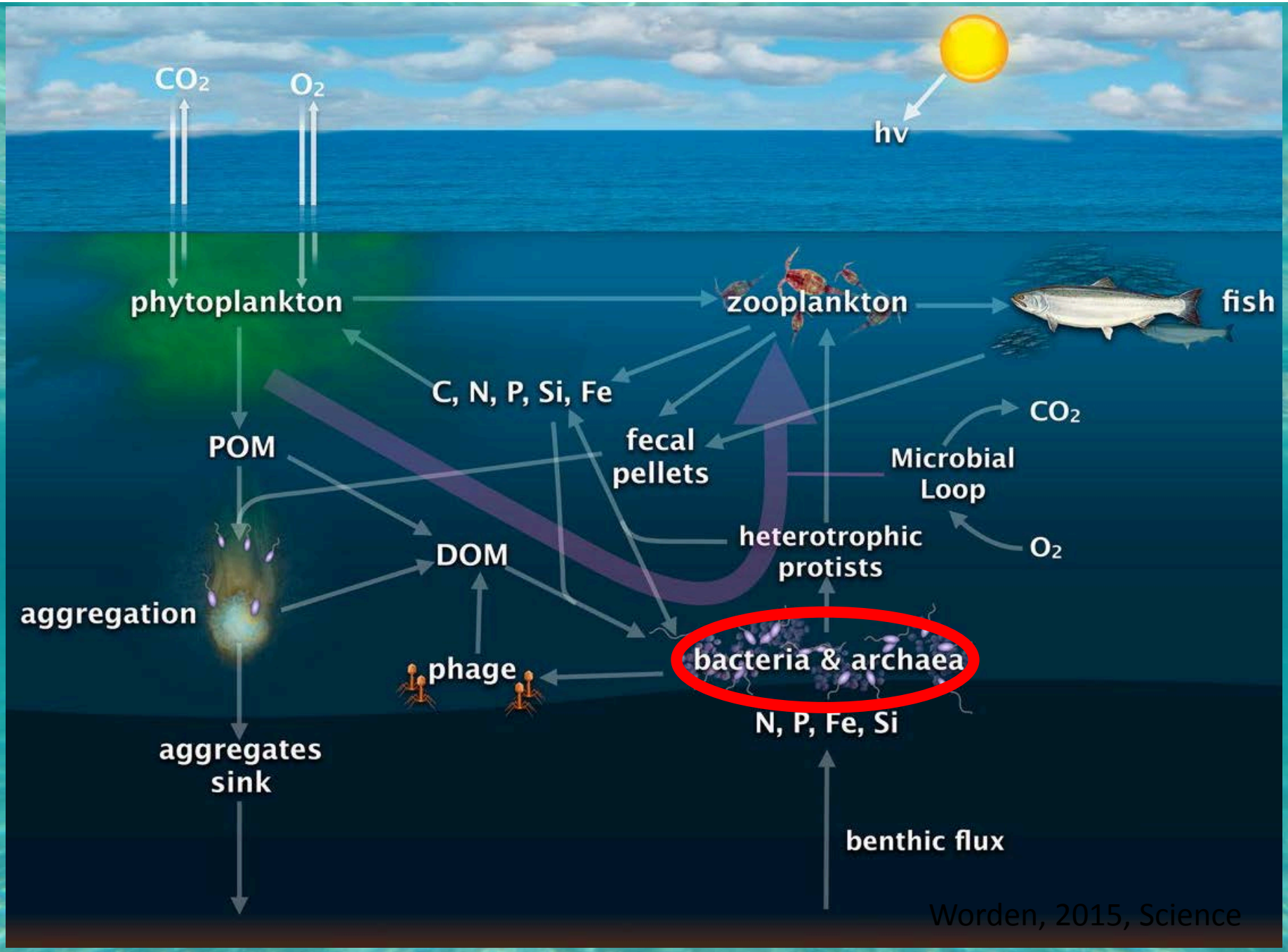

Worden, 2015, Science

Tržaški zaliv (S Jadran) = dinamičen obalni morski ekosistem
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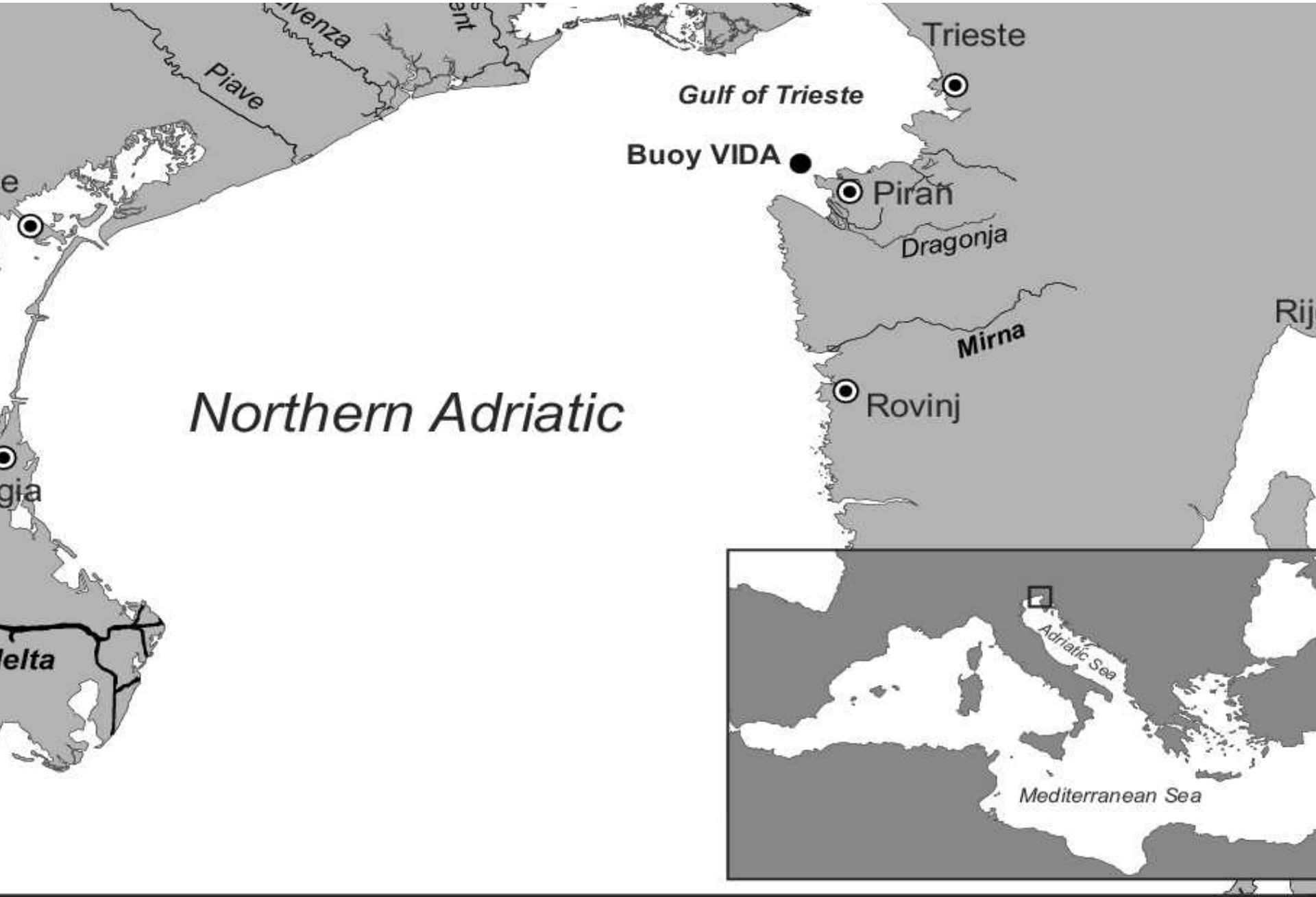

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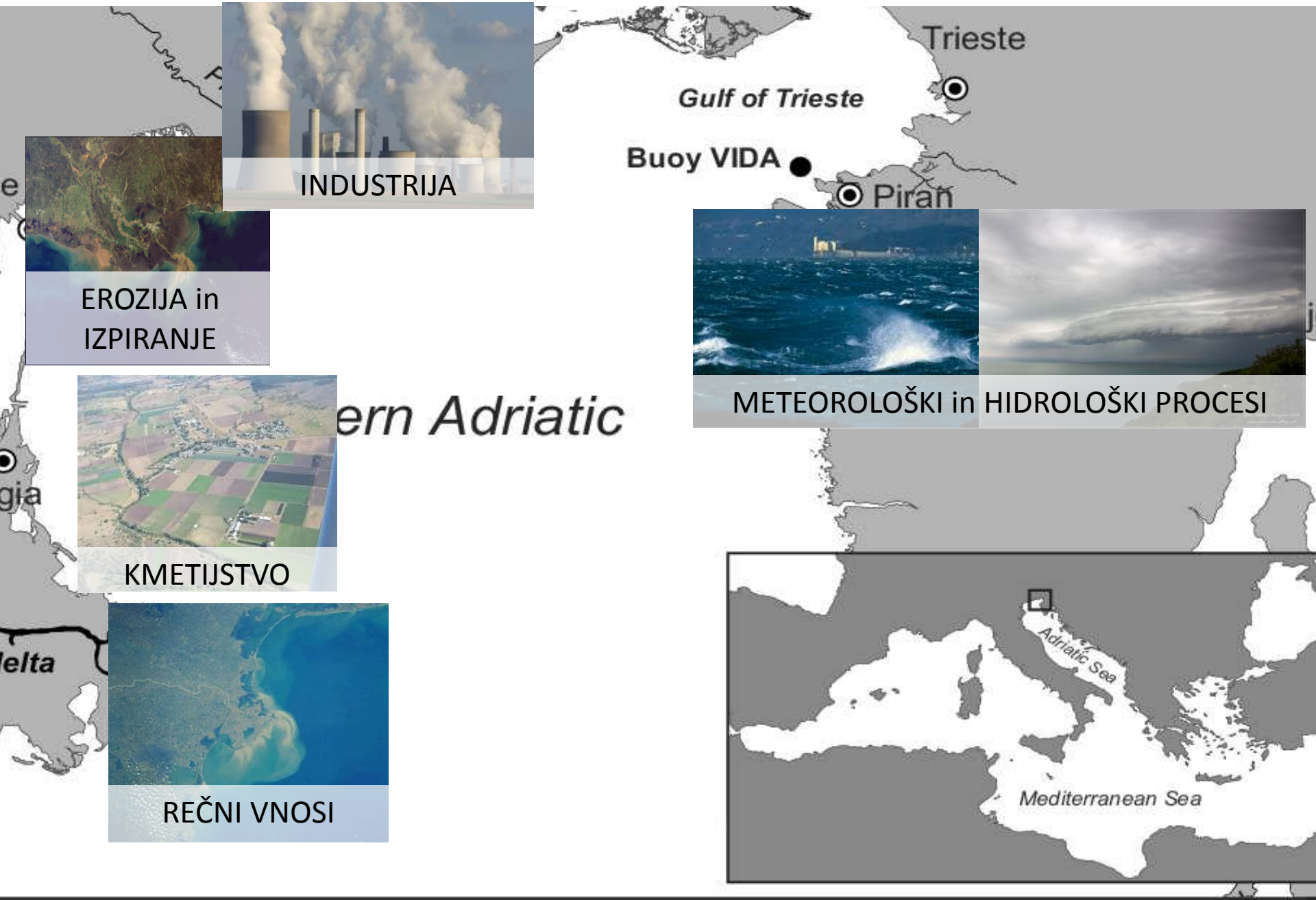

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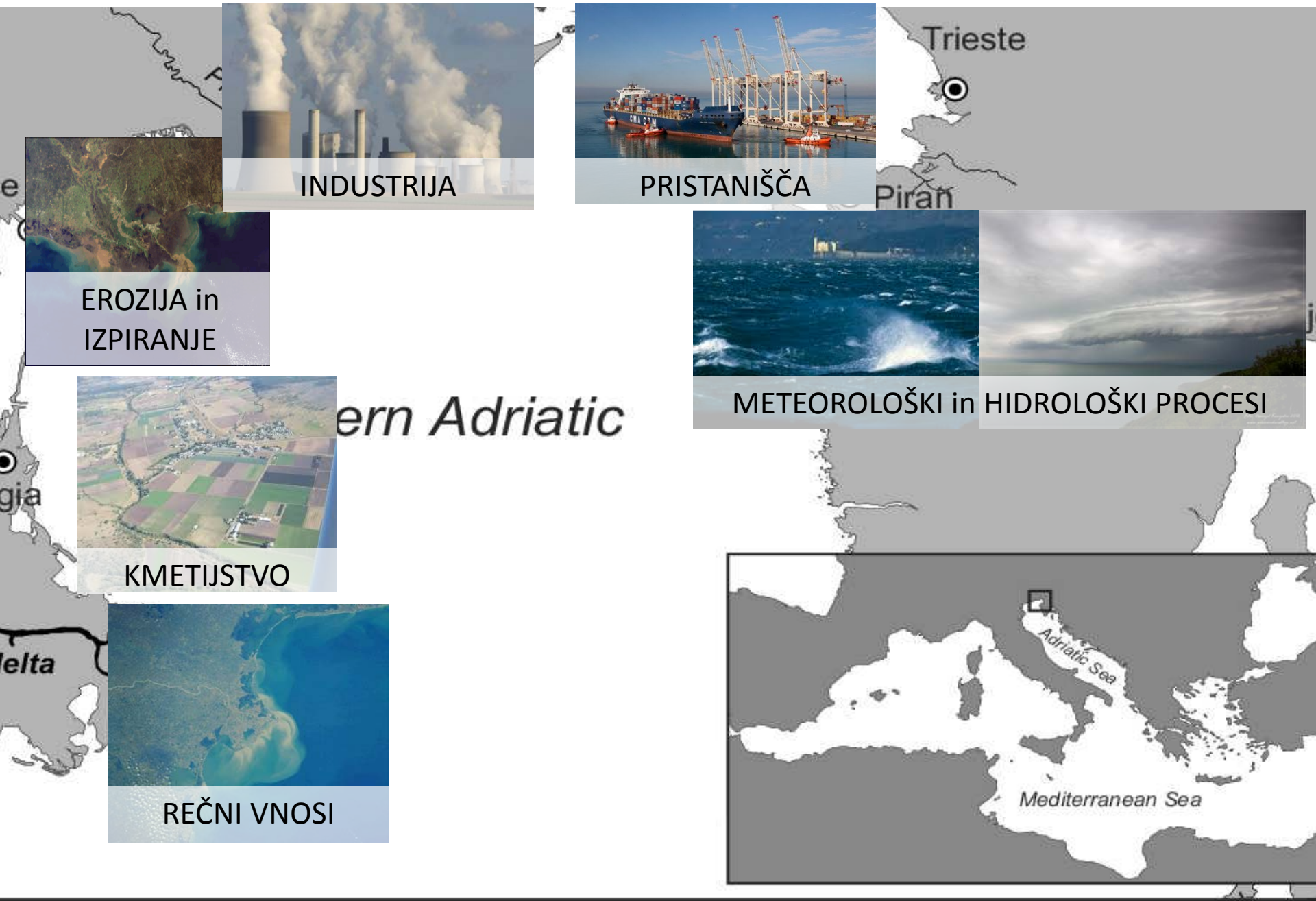

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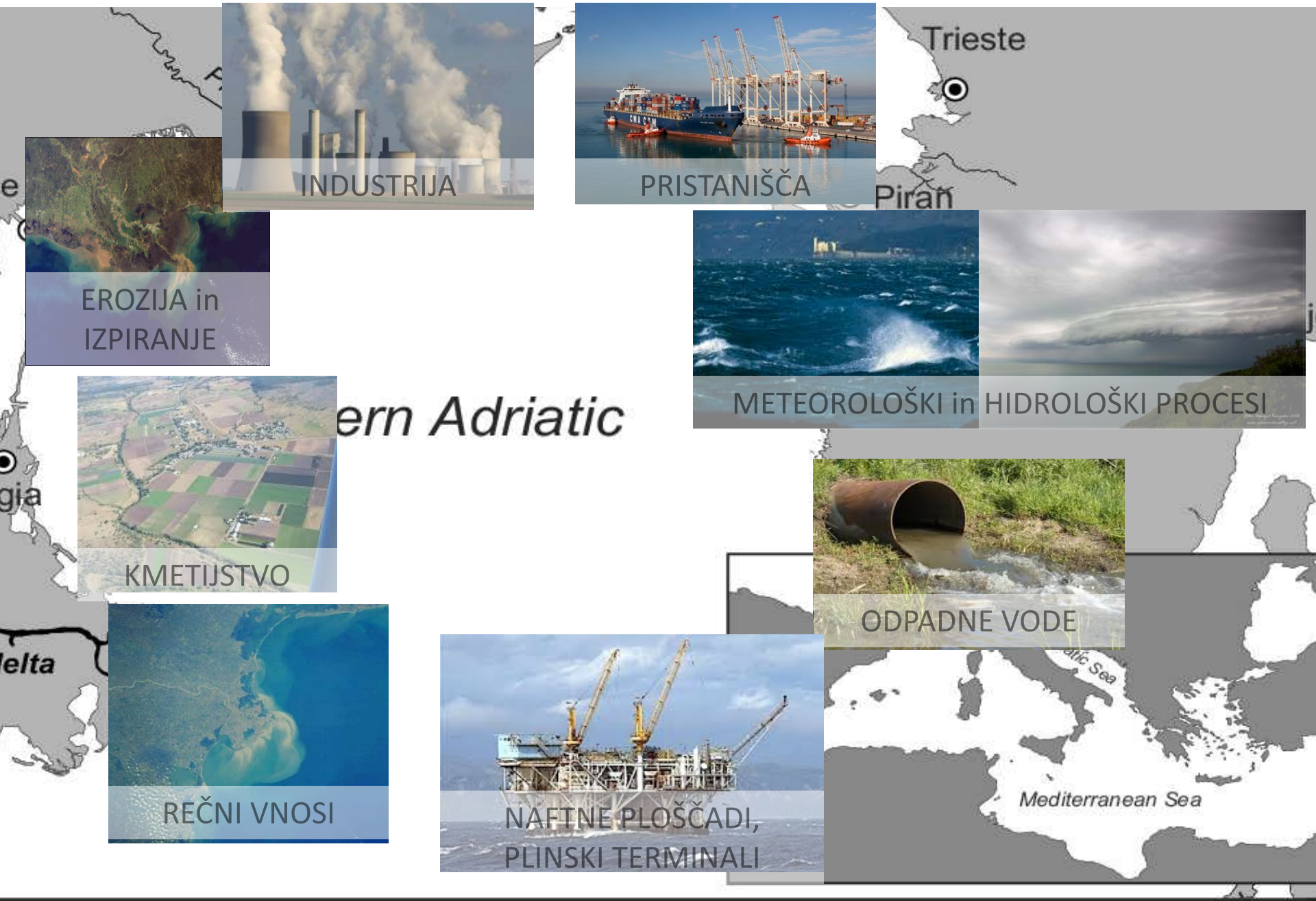

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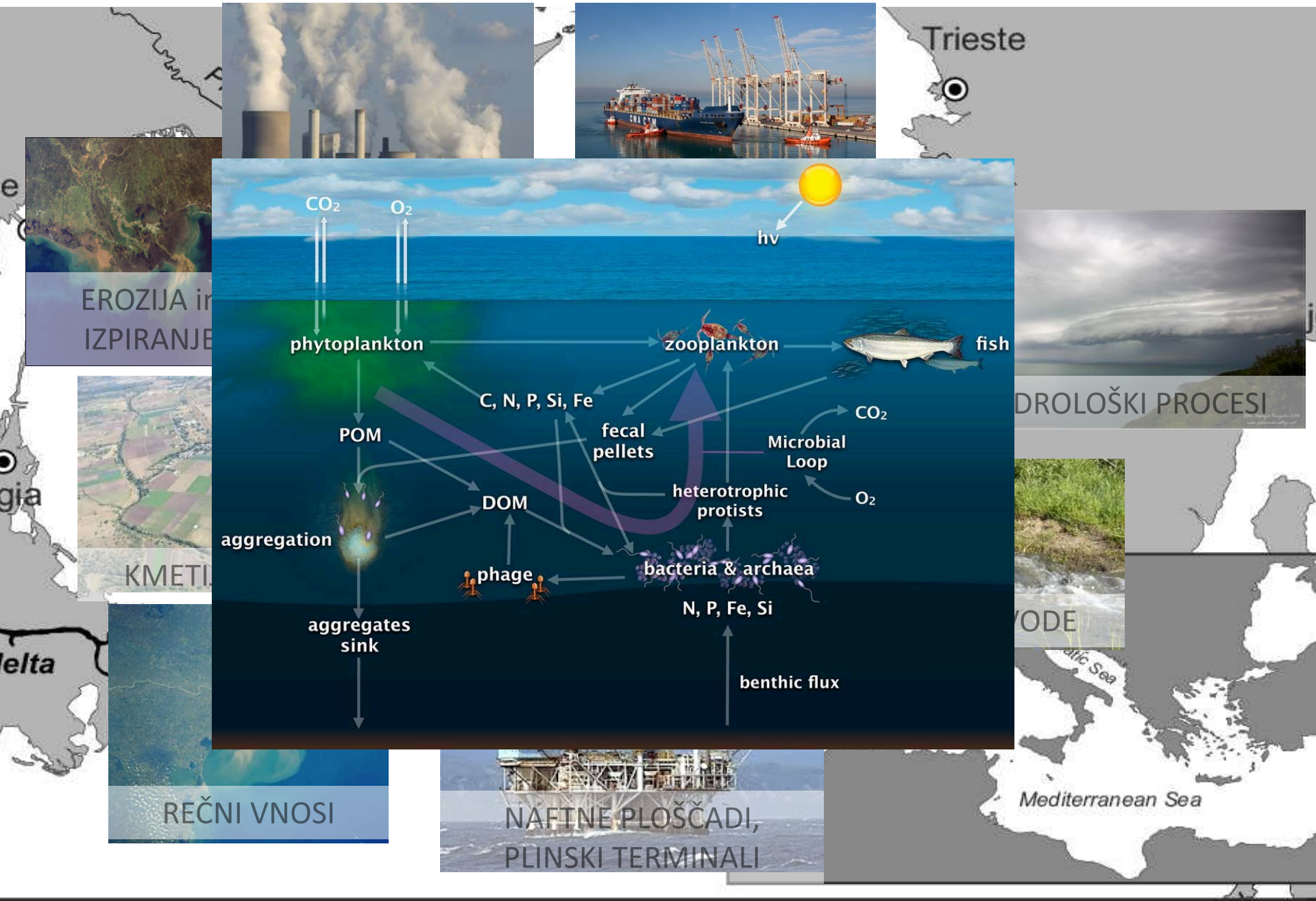

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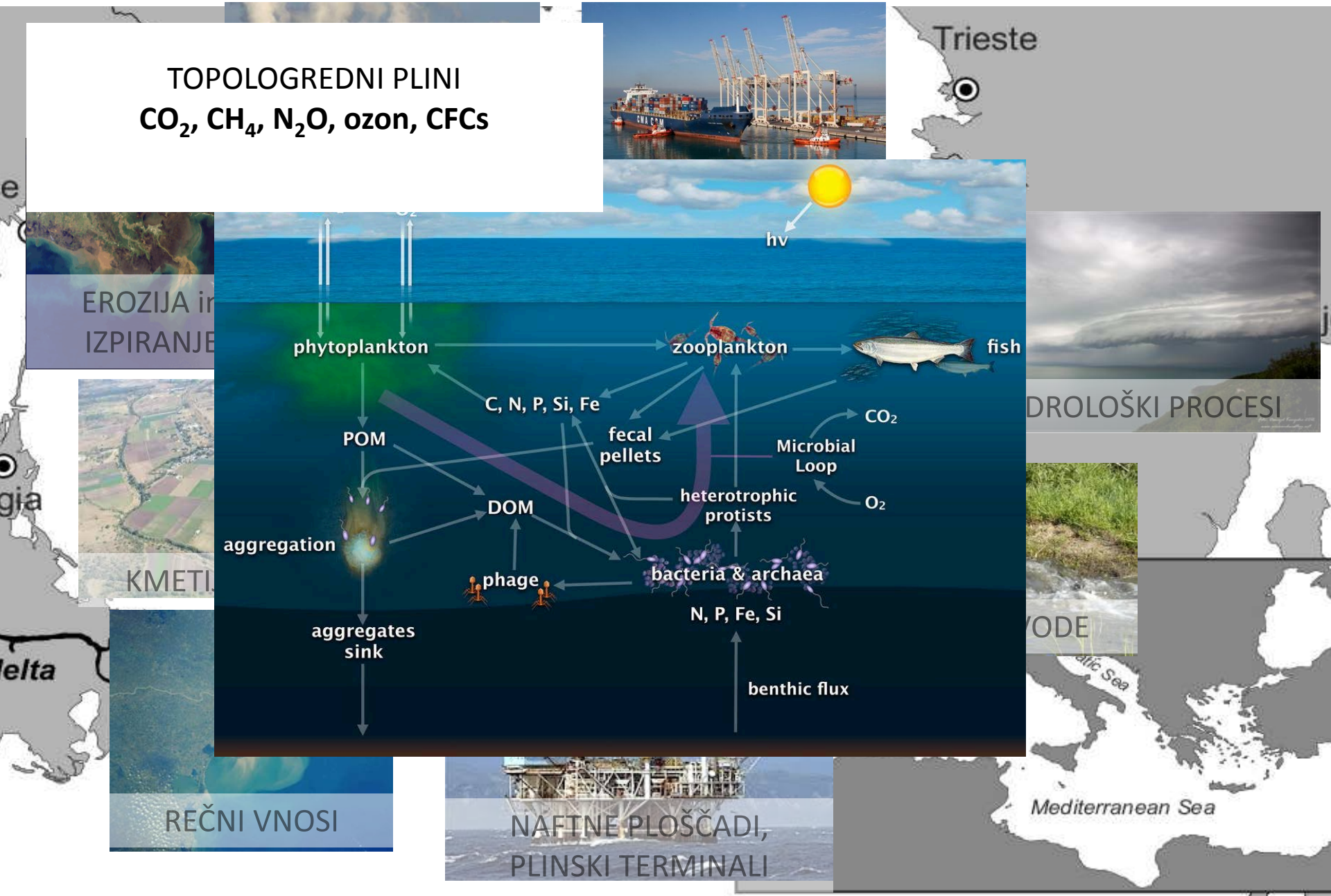
TOPOLOGREDNI PLINI
CO_2, CH_4, N_2O, ozon, CFCs



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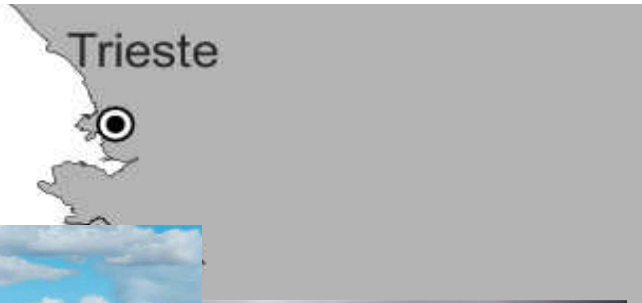
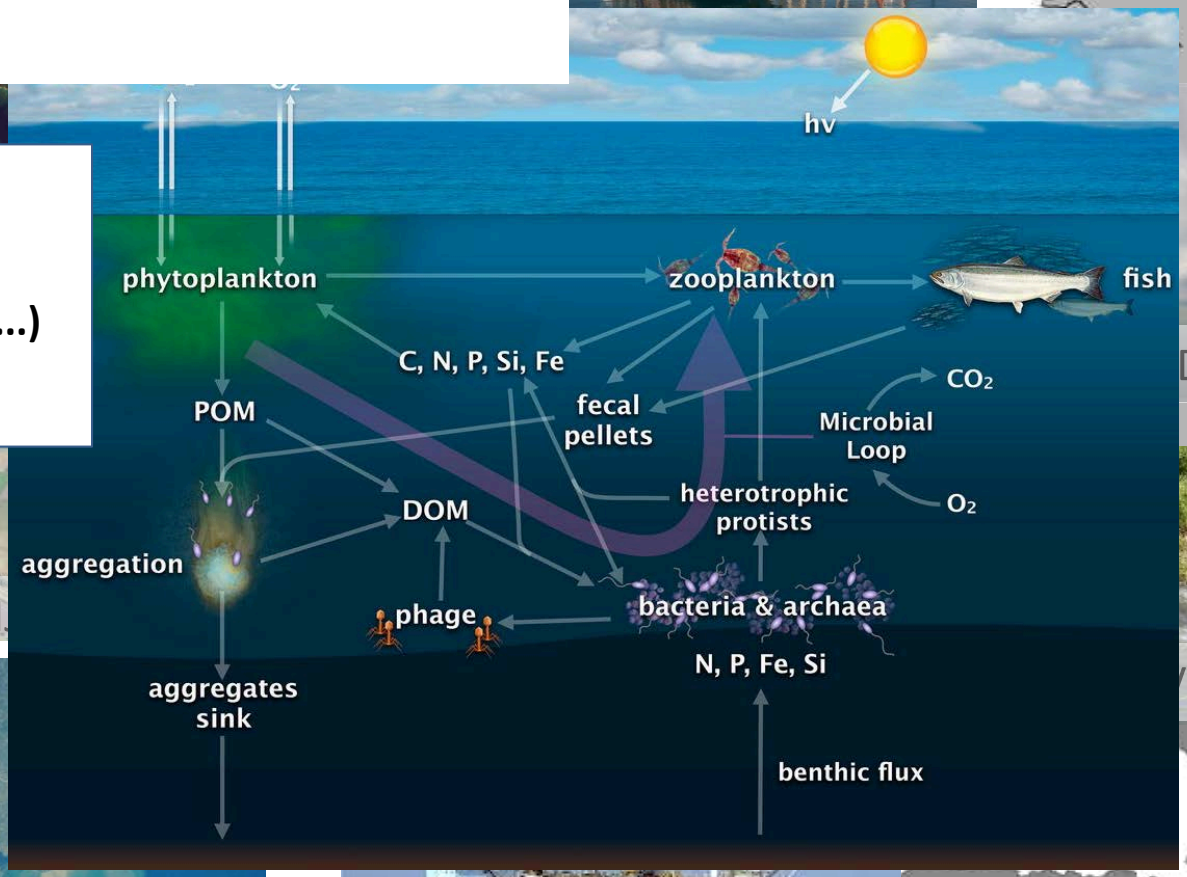
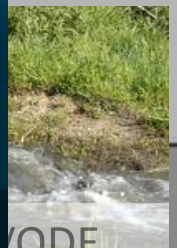


HRANILA
(C,N,P, S, Fe...)

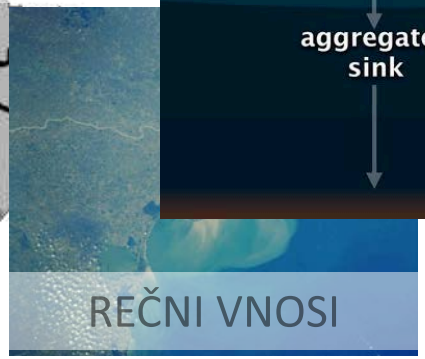


DROLOŠKI PROCESI

KMETI



VODE



REČNI VNOSI

NAFTNE PLOŠČADI,
PLINSKI TERMINALI

Tržaški zaliv (S Jadran) = dinamičen obalni morski ekosistem
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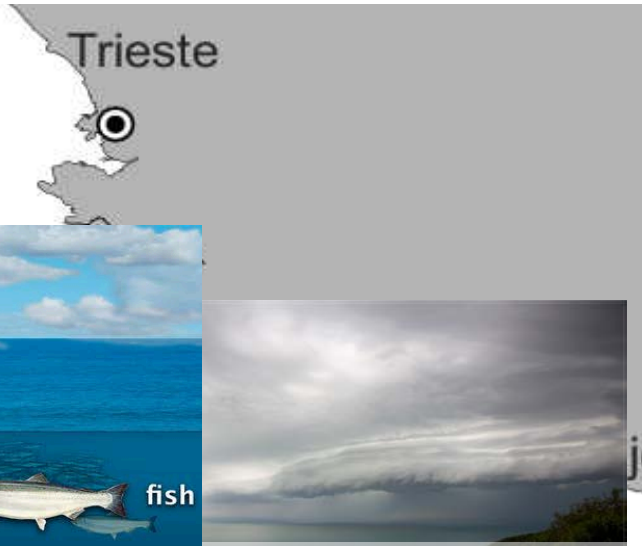

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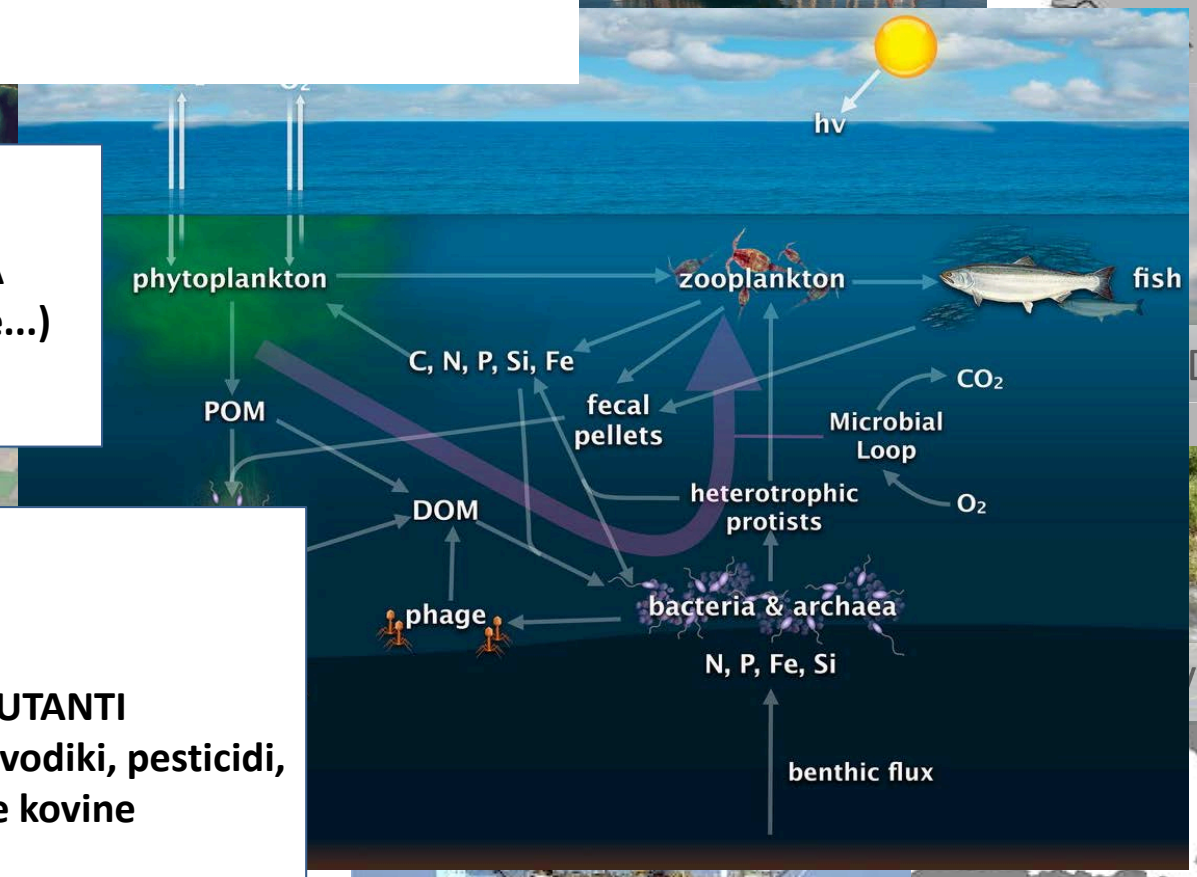

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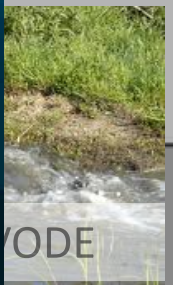

VODE

POLUTANTI
naftni ogljikovodiki, pesticidi, težke kovine

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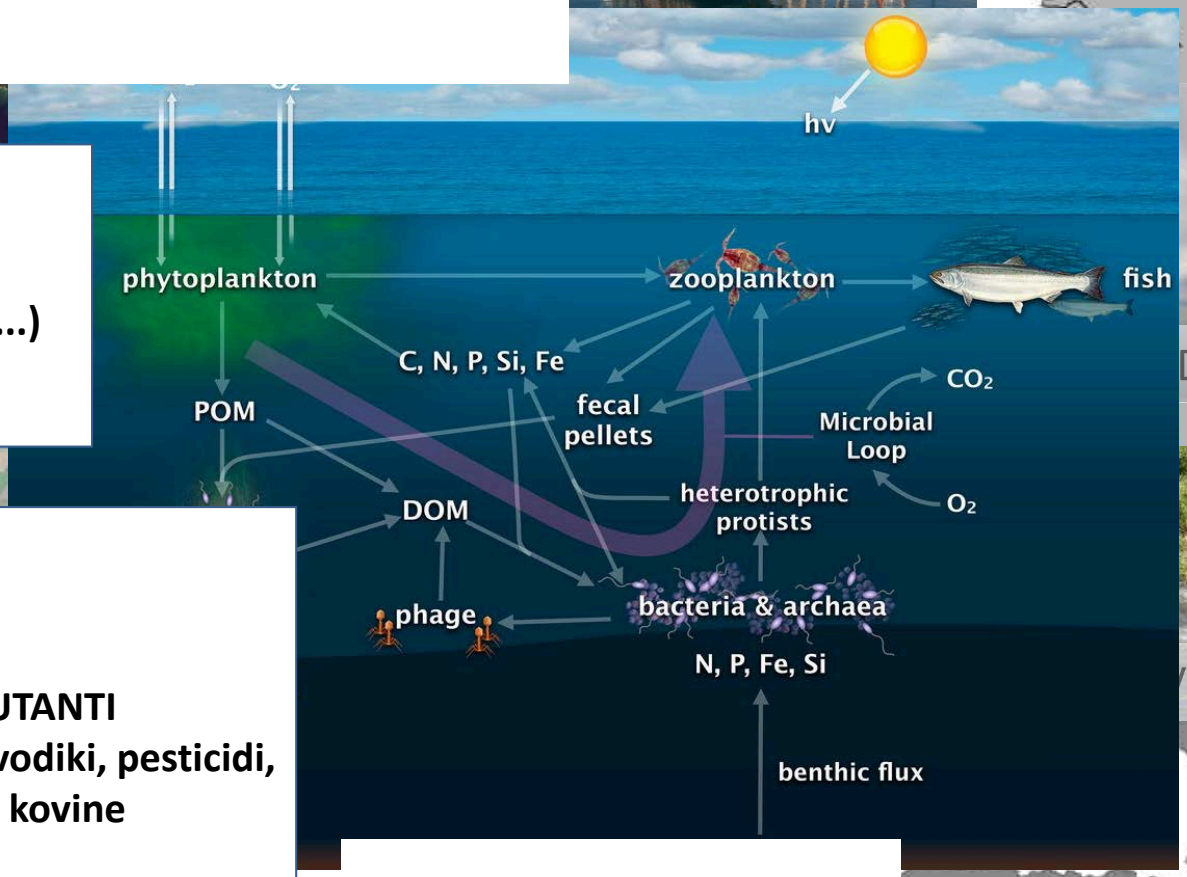

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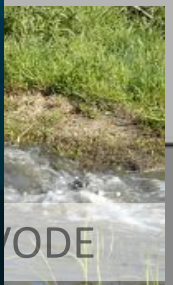

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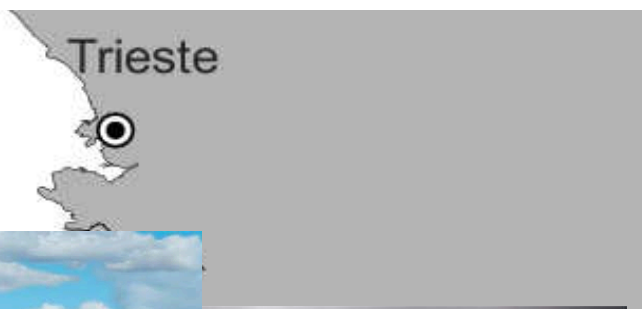

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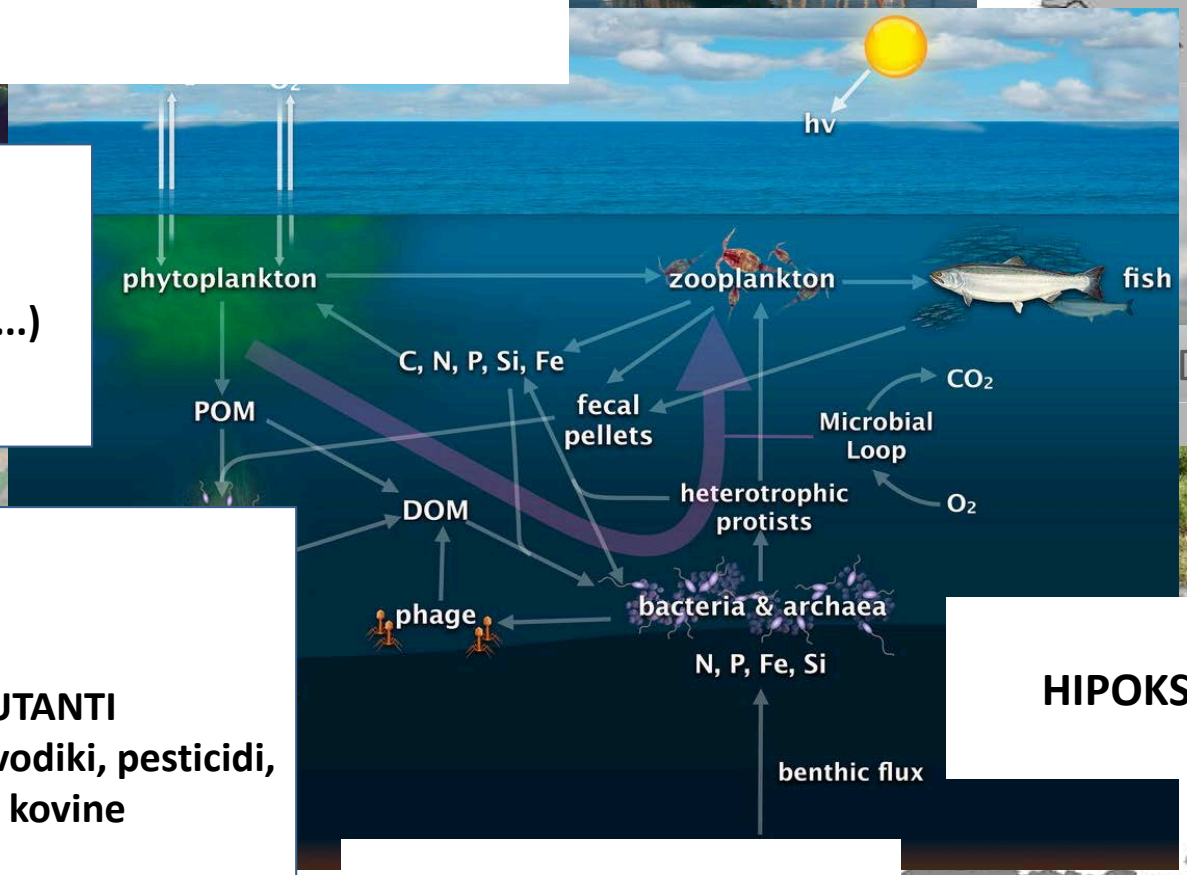

DROLOŠKI PROCESI

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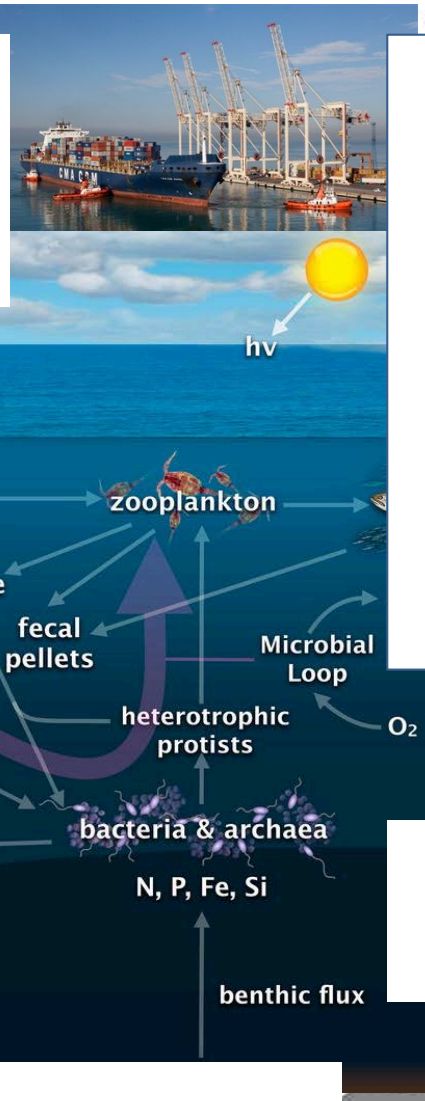
TOPOLOGREDNI PLINI
CO_2, CH_4, N_2O, ozon, CFCs

KLIMATSKE SPREMEMBE
Temperatura morja
Gladina morja
Veter, tokovanje
Hidrološki cikli
Cirkulacija, stratifikacija
Ekstremni meteorološki pojavi
Zakisanje morja

HRANILA
(C,N,P, S, Fe...)



POLUTANTI
naftni ogljikovodiki, pesticidi, težke kovine

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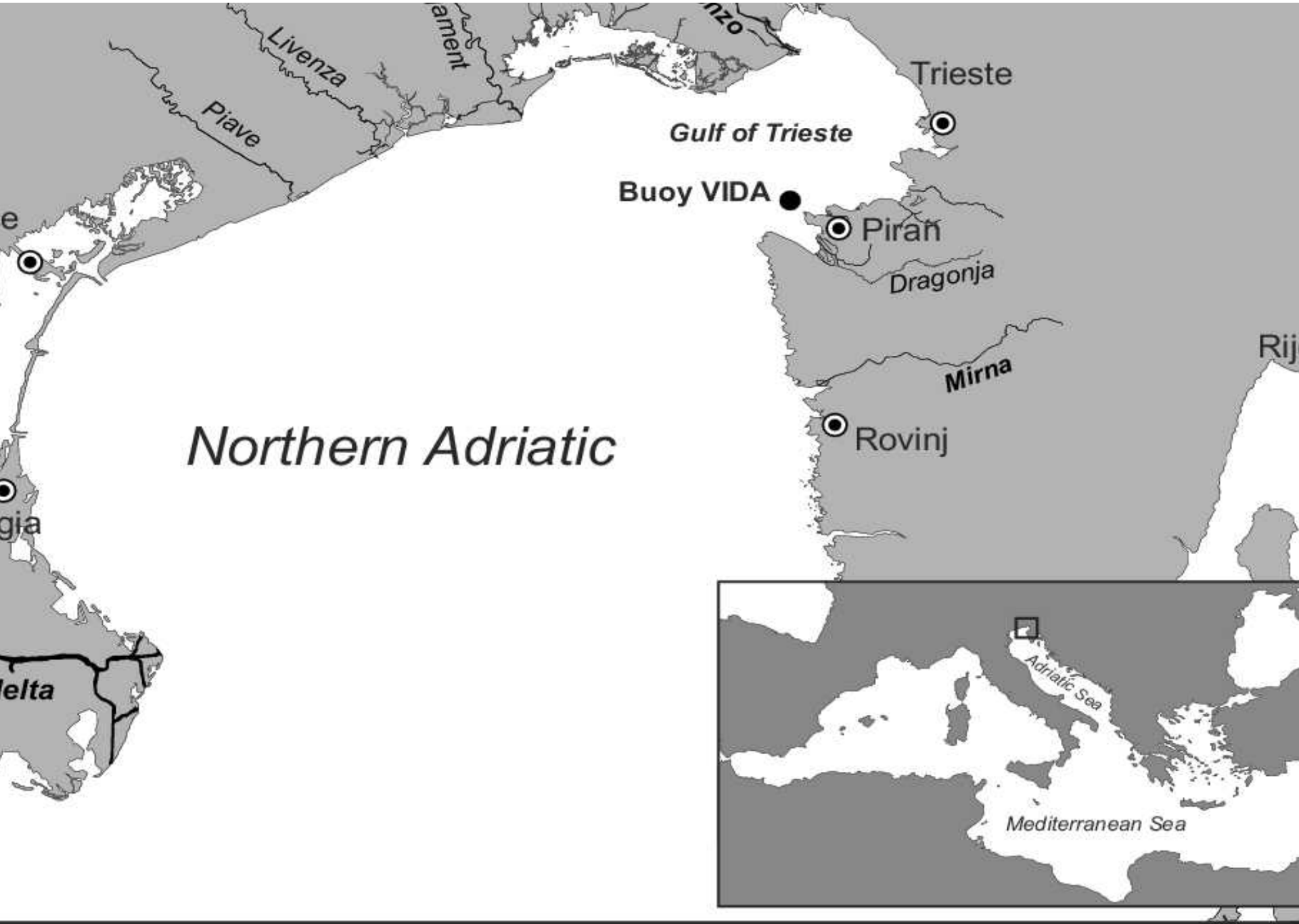
EUTROFIKACIJA

DOLGOROČEN NIZ FIZIKALNIH, KEMIJSKIH IN BIOLOŠKIH PARAMETROV



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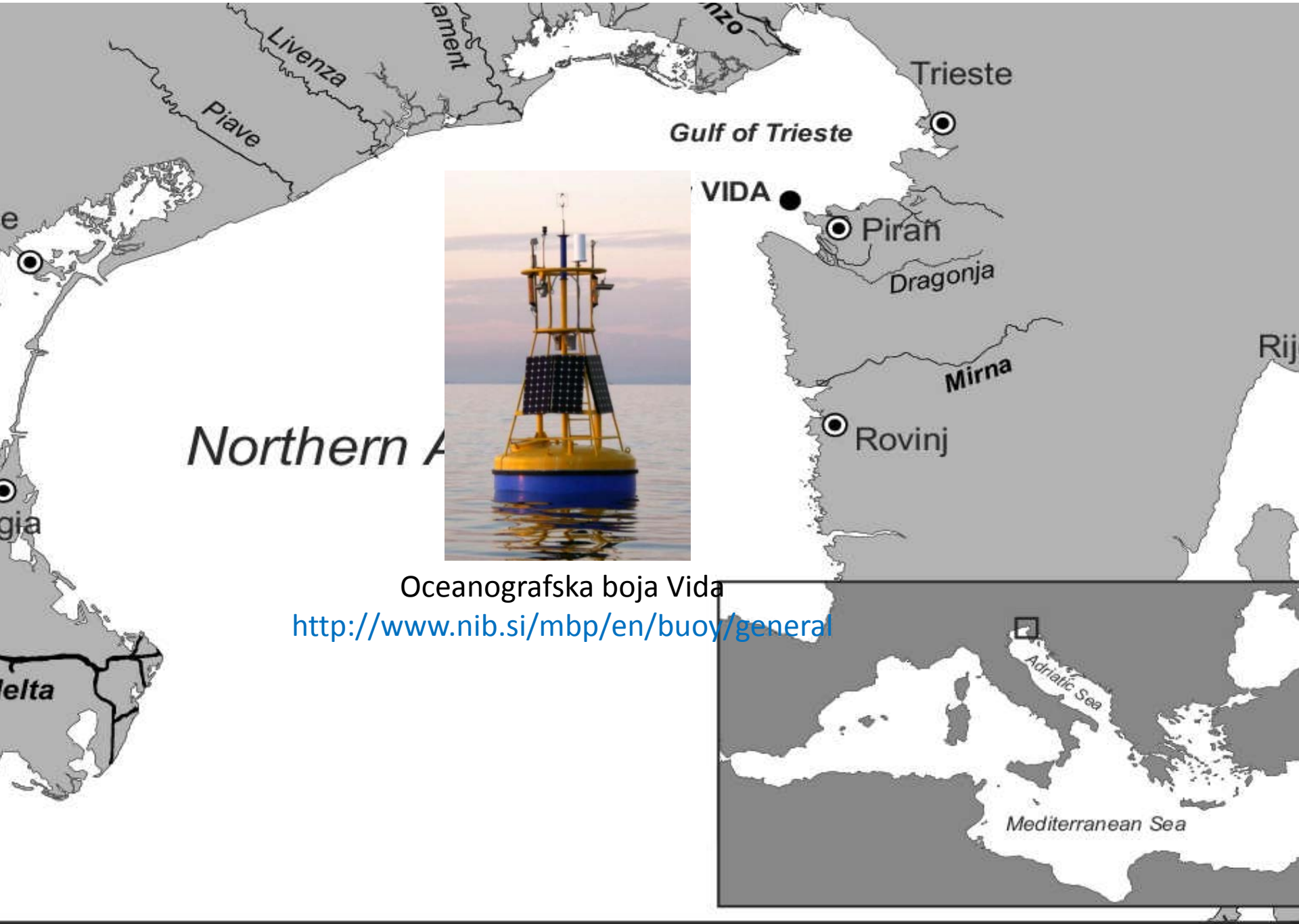
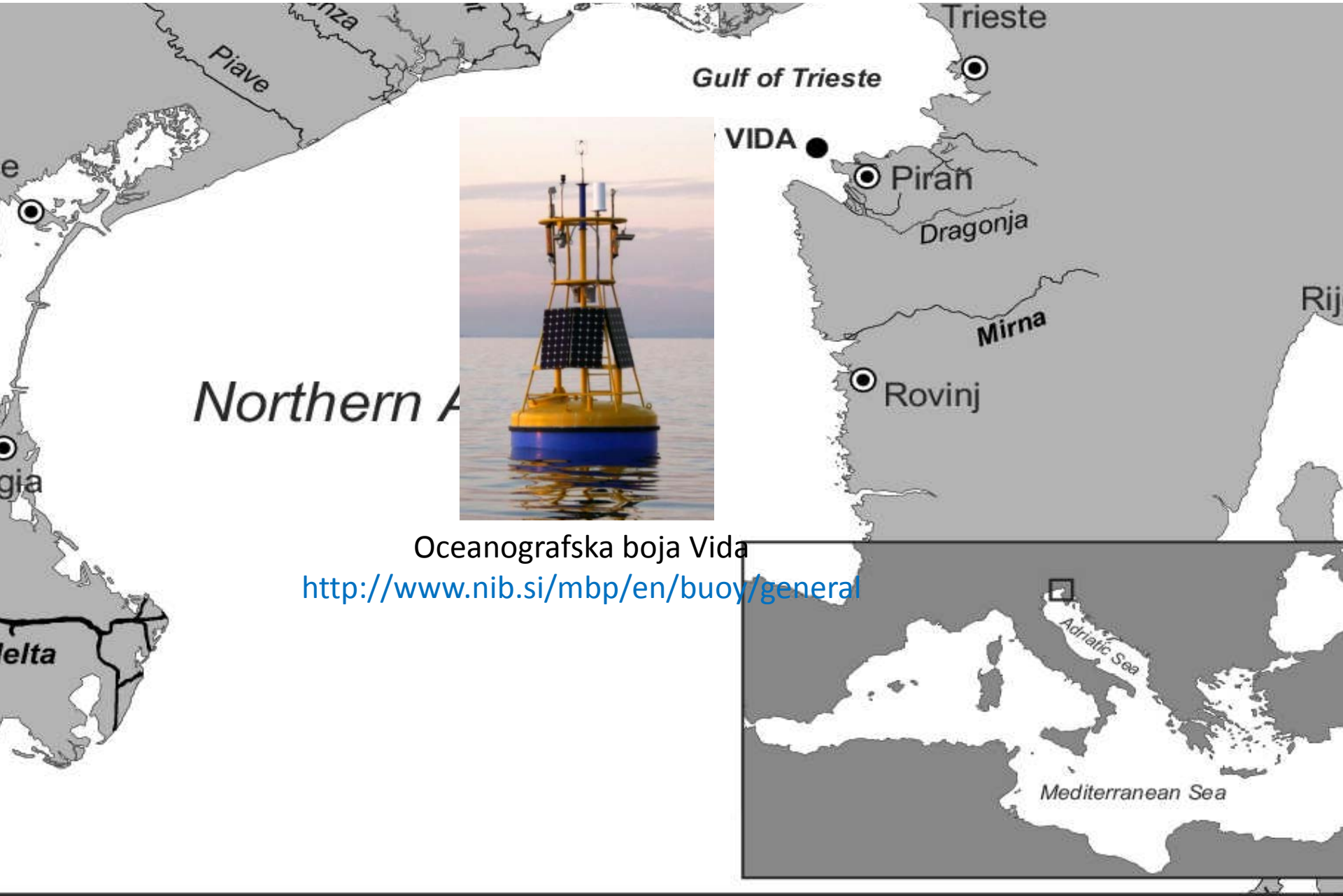


Oceanografska boja Vida
http://www.nib.si/mbp/en/buoy/general

DOLGOROČEN NIZ FIZIKALNIH, KEMIJSKIH IN BIOLOŠKIH PARAMETROV

2 leti (Januar 2009 – December 2010) 2-krat mesečno na površju in na dnu vodnega stolpca



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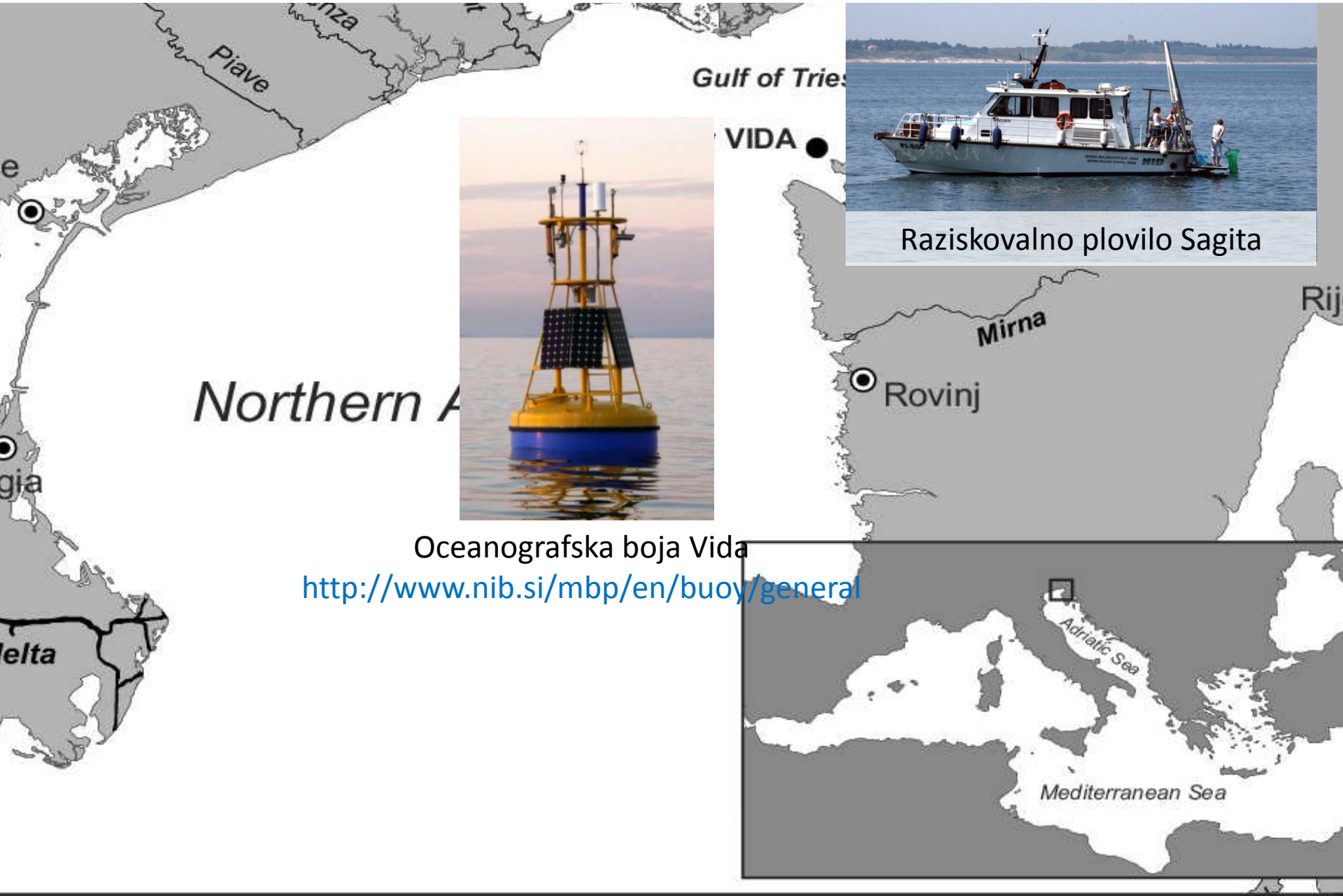

Raziskovalno plovilo Sagita

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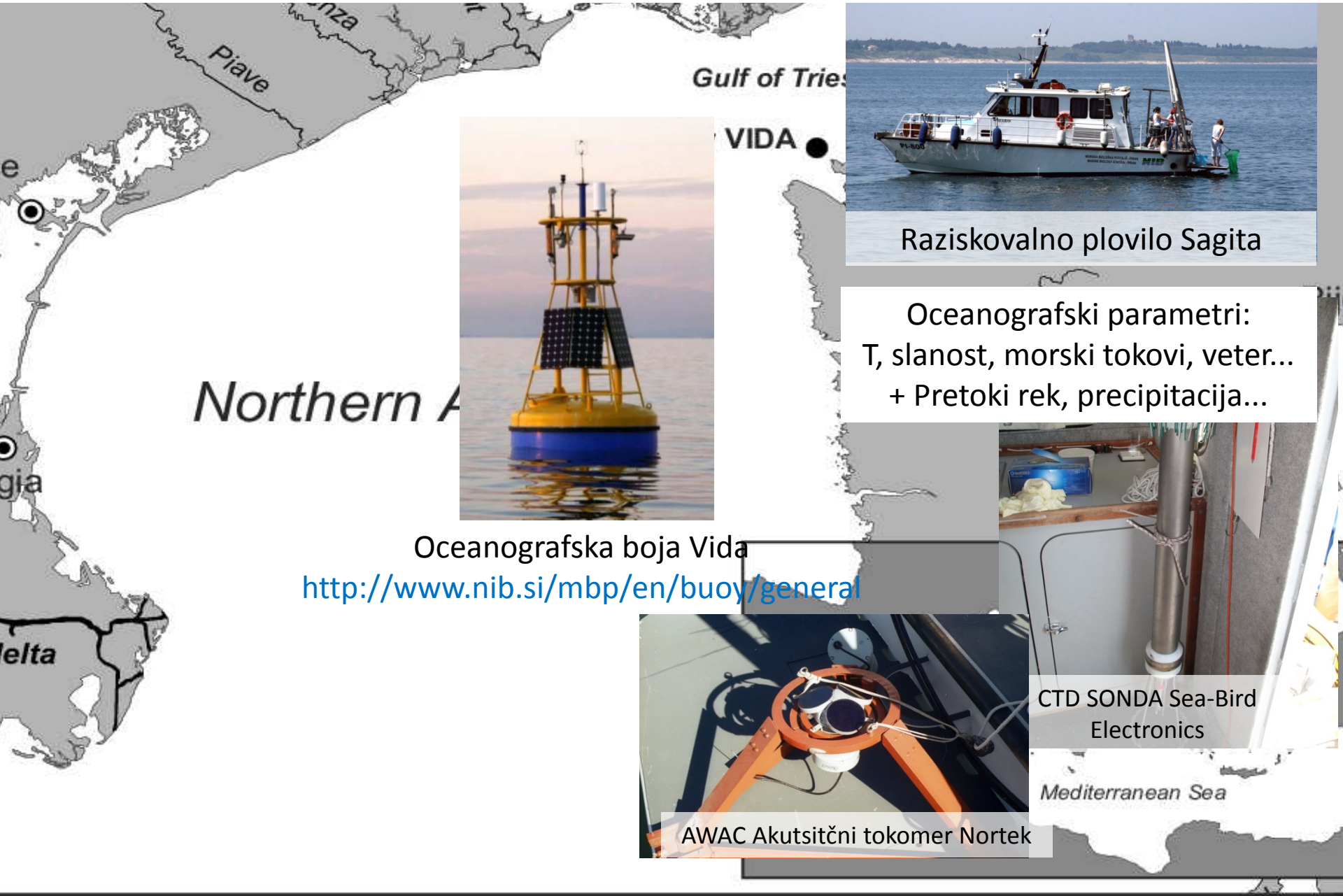

Raziskovalno plovilo Sagita

Oceanografski parametri:
T, slanost, morski tokovi, veter...
+ Pretoki rek, precipitacija...

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CTD SONDA Sea-Bird Electronics

AWAC Akutsitčni tokomer Nortek

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2 leti (Januar 2009 – December 2010) 2-krat mesečno na površju in na dnu vodnega stolpca

Kemijski in biološki parametri

Vzorčevalna rozeta z Niskin vzorčevalniki

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Raziskovalno plovilo Sagita

Oceanografski parametri:
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CTD SONDA Sea-Bird Electronics

Število, produktivnost, sestava bakterijske združbe
Število, sestava fitoplanktonske združbe
Koncentracija organskih in anorganskih hranil

AWAC Akutsitčni tokomer Nortek

Mediterranean Sea

ASOCIACIJSKE MREŽE

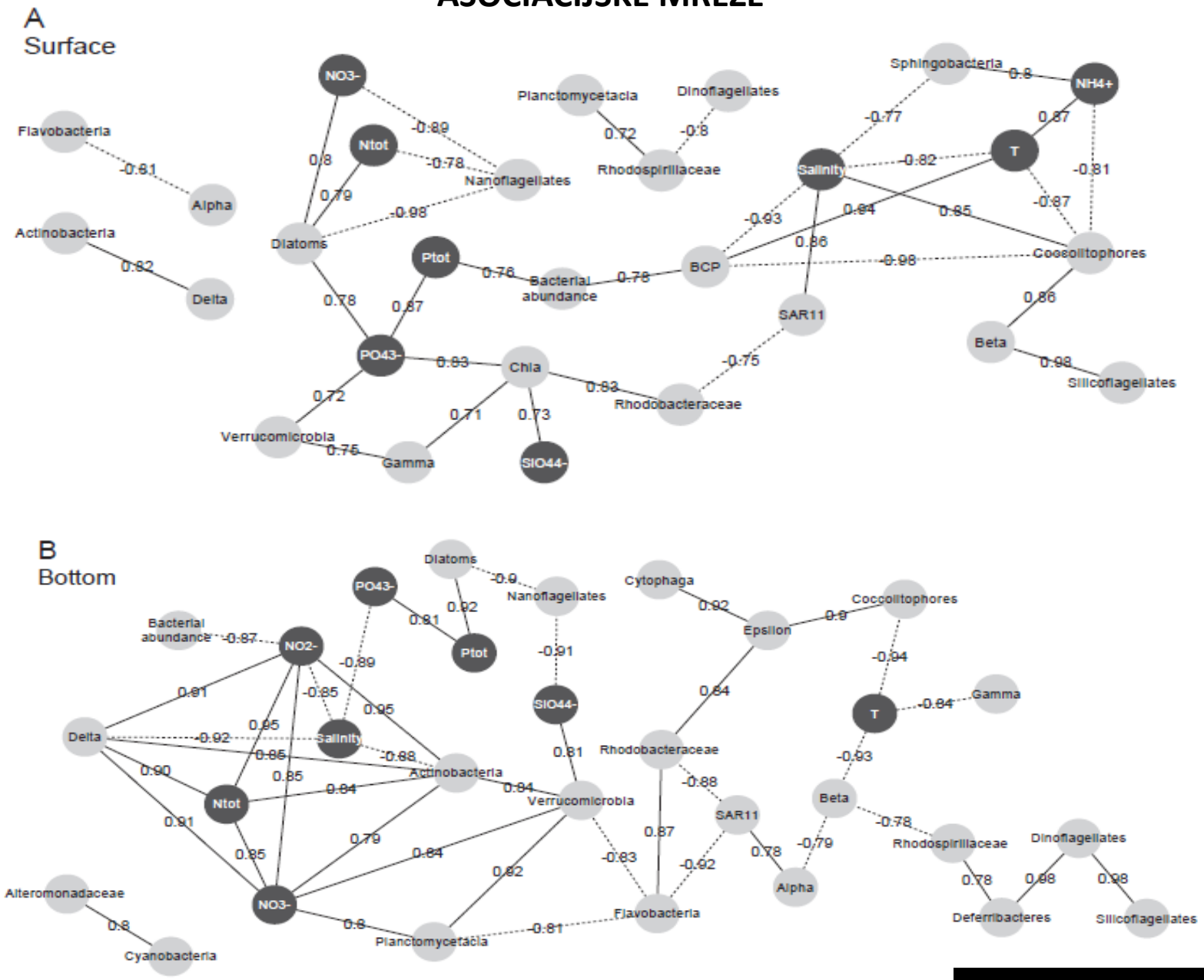
ASOCIACIJSKE MREŽE

	T	Salinity	O2	PO43-	Ptot	NO2-	NO3-	NH4+	SiO44-	Ntot	N	BCP	Chla	Alpha	SAR11	Rhodab	Rhodarpi	Gamma	Alteroman	SAR86	Beta	Delta	Flavob-ac	Sphingob	Cytopha-	Actinob-a	Cyanob-acte	Planctom	Verrucom	Diatomejo	Dinaflaq.	Cacc	Silicaflaq.
T																																	
Salinity	0.03860307																																
O2	0.16788794	0.41685468																															
PO43-	0.63591412	0.16420915	0.64091207																														
Ptot	0.24790551	0.07319945	0.6642036	0.01327																													
NO2-	0.12949265	0.73864009	0.01450625	0.30016	0.92619																												
NO3-	0.91743493	0.56421628	0.22037922	0.10982	0.49756	0.14103																											
NH4+	0.02251906	0.09760874	0.09885966	0.9365	0.64938	0.11914	0.43896																										
SiO44-	0.5742798	0.42525747	0.73965377	0.12289	0.09441	0.72963	0.50528	0.64935																									
Ntot	0.33456602	0.29287833	0.9453847	0.12761	0.18155	0.77326	0.15394	0.47052	0.72483																								
N	0.17328824	0.24830744	0.46843634	0.26984	0.04088	0.32535	0.82578	0.76063	0.31457	0.5709																							
BCP	0.03109512	0.03908797	0.36673681	0.27905	0.09309	0.30843	0.54997	0.26303	0.6593	0.28813	0.05317																						
Chla	0.98320713	0.53990231	0.56186197	0.02038	0.06739	0.15619	0.2912	0.56156	0.0552	0.24945	0.55877	0.99030563																					
Alpha	0.5863121	0.9373002	0.85992322	0.5127	0.41463	0.27771	0.63505	0.93805	0.93654	0.76233	0.76099	0.67929815	0.28569																				
SAR11	0.1930845	0.02552025	0.29630456	0.10769	0.12083	0.66164	0.49506	0.27646	0.33821	0.36348	0.89426	0.34883268	0.19068	0.55697																			
Rhodab-acteraceae	0.9638501	0.33381574	0.79975844	0.03808	0.2328	0.06825	0.27031	0.83156	0.24872	0.30933	0.71074	0.84474524	0.02101	0.18757	0.04733																		
Rhodarpirillaceae	0.63331789	0.10392093	0.93067448	0.09637	0.07002	0.41464	0.43051	0.9296	0.28446	0.75183	0.37324	0.24428688	0.29072	0.29561	0.09082	0.17731																	
Gamma	0.82120987	0.89105579	0.47435516	0.16475	0.14531	0.47883	0.89934	0.62178	0.38369	0.60906	0.39558	0.92282491	0.06199	0.19793	0.27718	0.13551	0.46682																
Alteromanadaceae	0.34436383	0.28910702	0.89975304	0.58343	0.7543	0.93557	0.07723	0.54005	0.7802	0.12736	0.98827	0.13929951	0.69233	0.33671	0.66383	0.94961	0.64182	0.326548															
SAR86	0.97020932	0.41518018	0.6587501	0.69784	0.68377	0.41184	0.17654	0.79419	0.52927	0.94551	0.24156	0.35694693	0.67062	0.53205	0.41507	0.74002	0.49301	0.3802	0.169161														
Beta	0.23675819	0.31513714	0.54611077	0.33834	0.40012	0.55458	0.77316	0.11111	0.79442	0.07572	0.63279	0.3487547	0.63175	0.95224	0.41896	0.83216	0.68223	0.694672	0.51876	0.83343													
Delta				0.60361	0.32136	0.48625	0.86346	0.58767	0.7535	0.90396	0.03145	0.16061708	0.82412	0.74286	0.57325	0.30691	0.4993	0.702796	0.721049	0.65361	0.76483												
Flavob-acteria	0.85906781	0.68136894	0.79306754	0.64725	0.32751	0.75062	0.3274	0.85562	0.84069	0.62741	0.34732	0.90983864	0.63244	0.02523	0.65674	0.61091	0.12383	0.500617	0.295847	0.59177	0.61501	0.689342											
Sphingob-acteria	0.07857328	0.05654041	0.25111264	0.92896	0.85118	0.54345	0.44946	0.02932	0.99123	0.96903	0.66956	0.72015536	0.80014	0.77529	0.15869	0.66607	0.53255	0.511454	0.949633	0.49315	0.54727	0.198652	0.4875										
Cytophaga	0.80782818	0.75091049	0.98247248	0.90572	0.7417	0.84885	0.79621	0.62511	0.79442	0.46706	0.80072	0.95023481	0.98957	0.14538	0.93788	0.73794	0.4993	0.622762	0.66791	0.59768	0.76483	0.764825	0.19198	0.54727									
Actinob-acteria	0.21463473	0.33702095	0.68881318	0.49932	0.28905	0.92854	0.99873	0.16163	0.3926	0.70087	0.07076	0.64669808	0.51545	0.66615	0.62607	0.85264	0.48599	0.176422	0.498435	0.24313	0.41122	0.023578	0.437	0.08188	0.75443								
Cyanob-acteria	0.62249994	0.65496571	0.3307372	0.4585	0.66031	0.60595	0.62156	0.67345	0.77935	0.20455	0.55215	0.79912854	0.19808	0.70676	0.17045	0.10084	0.75593	0.134176	0.940083	0.88547	0.21493	0.210018	0.44234	0.86307	0.61566	0.52114							
Planctomycotar	0.39041806	0.19614725	0.30580834	0.90997	0.41245	0.55931	0.45505	0.3534	0.88192	0.4763	0.40801	0.27058077	0.67273	0.49963	0.30365	0.97371	0.05911	0.997996	0.991601	0.75421	0.52223	0.483566	0.07995	0.19071	0.48357	0.71665	0.3470958						
Verrucomicrobia	0.9759199	0.36219077	0.20419368	0.05879	0.11067	0.23854	0.30614	0.88237	0.74628	0.35182	0.55478	0.41760433	0.15238	0.18923	0.09112	0.0871	0.08537	0.044809	0.791765	0.58889	0.61216	0.612155	0.41531	0.82206	0.93891	0.41128	0.3011318	0.52192					
Diatomejo	0.84708037	0.33146186	0.59965584	0.08346	0.21348	0.20793	0.07266	0.96923	0.80377	0.07905	0.78637	0.36478268	0.27587	0.49148	0.19995	0.12356	0.2244	0.657247	0.181029	0.38159	0.44308	1	0.88226	0.95195	0.53125	0.8188	0.4720487	0.90969	0.13347				
Dinaflaq.	0.50050143	0.82448462	0.71624689	0.63697	0.67703	0.14658	0.69435	0.55854	0.96238	0.89991	0.81537	0.72573541	0.64877	0.12073	0.5262	0.23256	0.07027	0.760817	0.978308	0.65471	0.30372	1	0.13376	0.87449	0.23961	0.55323	0.603361	0.25833	0.2867	0.3715828			
Cacc	0.07345311	0.08297578	0.50692428	0.2994	0.16067	0.55811	0.77998	0.06538	0.95991	0.10263	0.16999	0.01190955	0.69836	0.78512	0.17918	0.71359	0.60418	0.927996	0.331336	0.80427	0.04321	1	0.82697	0.24013	0.59425	0.28556	0.5158132	0.73354	0.56207	0.2734674	0.75692		
Silicaflaq.	0.23479169	0.46437819	0.4386642	0.5643	0.49493	0.39263	0.9013	0.17577	0.75274	0.17596	0.29638	0.16503222	0.86427	0.7593	0.49409	0.93066	0.57262	0.6873	0.554797	0.99308	0.005	1	0.50424	0.74789	0.66173	0.41142	0.1571821	0.56189	0.70297	0.6239769	0.19894	0.08688	
nanaflaqel.	0.92632585	0.42101692	0.4207703	0.09096	0.27798	0.1805	0.02985	0.85379	0.70469	0.08085	0.90343	0.44150883	0.2683	0.69078	0.30369	0.15155	0.31357	0.755117	0.147571	0.36917	0.50111	1	0.88152	0.76814	0.63835	0.82765	0.5010878	0.68582	0.21205	0.0047755	0.46481	0.36463	0.679274577

	T	Salinity	O2	PO43-	Ptot	NO2-	NO3-	NH4+	SiO44-	Ntot	N	BCP	Chla	Alpha	SAR11	Rhodobacteraceae	Rhodarpirillac	Gamma	Alteromonadac	SAR86	Beta	Delta	Epsilon	Unclassified Proteobacteria	Flavobacteria	Sphingobacteria	Cytophaga	Unclassified Bacte	Actinobacteria	Cyanobacteria	Planctomycetes	Verrucomicrobia	Deferribacteres	Diatomejo
T	1																																	
Salinity	-0.1118784	1																																
O2	-0.6803153	-0.6804597	1																															
PO43-	-0.2061053	-0.8923179	0.90973538	1																														
Ptot	0.37579422	-0.6933899	0.4127517	0.81061	1																													
NO2-	0.14090177	-0.8507535	0.54245885	0.43222	0.22507	1																												
NO3-	0.33897169	-0.783121	0.05328822	0.51326	0.30872	0.85494	1																											
NH4+	0.66217244	-0.4501566	0.03091268	0.28839	0.596	0.12759	0.42455	1																										
SiO44-	0.71832276	-0.7426679	-0.1289796	0.65648	0.77775	0.5013	0.73539	0.73889	1																									
Ntot	0.13898178	-0.7462062	0.36029746	0.36388	0.15553	0.94902	0.84932	0.14665	0.42951	1																								
N	0.32564139	0.50823745	-0.6845449	0.31988	0.24309	-0.8673	0.0136	0.07495	0.4134	-0.668	1																							
BCP	0.33390074	0.31165798	0.01967788	0.38385	0.62277	-0.3991	-0.1039	0.45146	0.3847	-0.2719	0.56248	1																						
Chla	0.15750406	0.33736047	0.25704212	-0.07	0.29146	-0.7128	-0.4786	0.53687	0.00442	-0.6302	0.28413	0.66666687	1																					
Alpha	0.57943648	0.22470123	-0.6974541	-0.1856	0.16103	0.04281	-0.1049	-0.1111	0.19016	-0.012	0.13738	0.12784549	-0.2054	1																				
SAR11	0.24950139	-0.1457487	-0.5055339	0.16328	0.15791	0.51882	0.29618	-0.3339	0.25745	0.45727	0.05232	-0.1117408	-0.6978	0.78218	1																			
Rhodobacteraceae	-0.4002822	0.09739784	0.44865501	0.05261	-0.0572	-0.5273	-0.2123	0.16272	-0.1986	-0.5801	0.26049	0.06752871	0.55372	-0.7591	-0.8848	1																		
Rhodarpirillaceae	0.63536003	0.61102285	-0.9433642	-0.6861	-0.3736	-0.2731	-0.1961	-0.0593	-0.1069	-0.1804	0.18044	0.09543653	0.00961	0.68284	0.32557	-0.5017	1																	
Gamma	-0.3411805	0.52565774	0.318014	0.21274	-0.0997	-0.5251	-0.4425	-0.5301	-0.3927	-0.542	0.55427	0.21219004	0.10331	-0.3277	-0.2165	0.51602	-0.3246	1																
Alteromanadaceae	-0.438021	0.39539762	0.33423485	-0.3327	-0.1787	-0.3097	-0.7217	-0.4872	-0.6793	-0.2645	-0.6486	-0.0877873	0.13085	0.19572	0.05233	-0.1554	0.01743	0.088574	1															
SAR86	0.02011645	0.28886808	-0.3637441	0.50394	0.32565	-0.0408	0.21979	-0.1008	0.3555	0.00543	0.82446	0.58181196	-0.1125	0.1948	0.3705	-0.157	0.08588	0.510783	-0.40808	1														
Beta	-0.9253287	-0.0912301	0.74877031	0.31902	-0.1589	-0.0609	-0.1077	-0.3959	-0.399	-0.0705	-0.0567	-0.200686	-0.076	-0.7968	-0.4325	0.6083	-0.7846	0.695254	0.097856	0.03076	1													
Delta	0.15142027	-0.9249008	0.5979595	0.50686	0.31239	0.91064	0.90701	0.41594	0.58341	0.90937	-0.5481	-0.2340838	-0.4213	-0.2645	0.16037	-0.2466	-0.4244	-0.52933	-0.44278	-0.1002	0.04861	1												
Epsilon	-0.4423745	0.0814223	0.19053872	0.03234	-0.1511	-0.4087	-0.32	-0.1521	-0.2278	-0.595	0.34587	-0.230856	0.17256	-0.4948	-0.536	0.84396	-0.4444	0.598413	-0.16621	-0.0923	0.5743	-0.326972	1											
Unclassified Proteo	0.208802	-0.3290611	0.5275979	0.24918	0.53751	0.0149	0.07685	0.73825	0.30801	0.12472	-0.3951	0.46406939	0.65569	-0.2596	-0.4419	0.15927	-0.283	-0.40465	0.137239	-0.3303	-0.0981	0.311419	-0.2958	1										
Flavobacteria	-0.5455153	0.32558312	0.67746313	-0.2498	-0.2975	-0.6367	-0.5734	-0.0231	-0.5638	-0.5996	-0.1775	-0.013792	0.60235	-0.7254	-0.9166	0.87087	-0.3678	0.429116	0.264076	-0.4091	0.59435	-0.380872	0.62765	0.26334	1									
Sphingobacteria	0.38545411	0.26716395	-0.5490257	-0.7217	-0.6338	-0.2323	-0.074	0.18755	-0.2445	-0.2247	-0.1213	-0.4212726	0.15822	-0.2547	-0.5209	0.34802	0.35599	-0.30512	-0.26277	-0.5418	-0.1713	-0.102645	0.28387	-0.0777	0.388	1								
Cytophaga	-0.1953189	0.2919304	-0.16463	-0.1058	-0.227	-0.5345	-0.2966	-0.0836	-0.1525	-0.6795	0.61327	-0.0812016	0.22749	-0.3474	-0.4945	0.77362	-0.1232	0.579918	-0.36141	0.10185	0.34491	-0.453381	0.91836	-0.4101	0.51363	0.42268	1							
Unclassified Bacte	0.32352117	0.44620847	-0.6055897	-0.8639	-0.6684	-0.1909	-0.3252	-0.0403	-0.494	-0.1996	-0.5673	-0.5922314	0.07437	-0.0267	-0.3256	0.10079	0.36894	-0.44436	0.258167	-0.8403	-0.2346	-0.186488	0.10049	-0.0119	0.34958	0.32983	0.1047919	1						
Actinobacteria	0.28196887	-0.8842008	0.25847191	0.46277	0.38875	0.95339	0.79066	0.243	0.61952	0.83627	-0.7063	-0.3479808	-0.6134	0.19277	0.55189	-0.5168	-0.2551	-0.59606	-0.29176	-0.0959	-0.2057	0.845326	-0.3477	0.07011	-0.6754	-0.2522	-0.482171	-0.1711	1					
Cyanobacteria	-0.4201542	0.65622582	0.09431493	-0.4392	-0.4223	-0.3466	-0.5922	-0.5951	-0.7458	-0.1545	-0.4276	0.0546595	0.03679	0.15286	0.09767	-0.2863	0.28639	0.2003	0.804802	-0.0652	0.08877	-0.460763	-0.39	-0.0332	0.16254	-0.2044	-0.41761	0.138	-0.4758	1				
Planctomycotar	0.44904026	-0.4444258	-0.8641897	0.30846	0.13106	0.66944	0.80339	0.0945	0.62949	0.60097	0.65867	-0.1464806	-0.6697	0.31108	0.62668	-0.495	0.18569	-0.2604	-0.72698	0.4779	-0.316	0.525274	-0.246	-0.4366	-0.8077	-0.0797	-0.08852	-0.3335	0.64591	-0.5284249	1			
Verrucomicrobia	0.54395384	-0.7018675	-0.6682135	0.48436	0.42797	0.77532	0.84126	0.30829	0.8148	0.65605	0.4754	-0.0886056	-0.5588	0.35588	0.62913	-0.501	0.01625	-0.42826	-0.64708	0.32791	-0.3852	0.656774	-0.2774	-0.1698	-0.8321	-0.2082	-0.213436	-0.3661	0.8367	-0.6551088	0.91969	1		
Deferribacteres	0.60576886	0.5178405	-0.8641897	-0.3429	-0.1948	-0.3284	0.04649	0.1651	0.17927	-0.2326	0.65867	0.36439749	0.1432	0.3492	0.08373	-0.1443	0.78383	-0.0241	-0.49246	0.48025	-0.5504	-0.326972	-0.1667	-0.2958	-0.261	0.35628	0.23714	0.01441	-0.3477	-0.0831367	0.38342	0.14924	1	
Diatomejo	0.21896219	-0.6537913	0.51136468	0.73224	0.91839	0.56313	0.54128	0.79209	0.83191	0.69478	-0.682	0.43996337	0.06163	-0.0476	0.15041	-0.381	-0.3	-0.70659	0.072088	-0.0226	-0.1198	0.722215	-0.7033	0.77696	-0.3072	-0.8095	-0.867042	-0.8011	0.55397	0.0872394	0.06081	0.33044	-0.361391217	1
Dinaflaq.	0.50199325	0.72463262	-0.8343617	-0.7205	-0.7575	-0.4097	-0.0852	-0.1496	-0.1998	-0.2985	0.92723	0.20615031	0.03981	0.21087	0.00046	-0.0551	0.77459	0.183462	-0.5133	0.75858	-0.2901	-0.449866	-0.044	-0.4925	-0.1007	0.80219	0.3604532	0.33801	-0.5163	0.1657757	0.30806	-0.044	0.975977848	-0.5281
Cacc	-0.9397832	-0.1937556	0.47709447	0.18437	-0.2612	-0.0856	-0.2341	-0.5559	-0.5625	-0.2933	-0.046	-0.6674927	-0.1304	-0.5495	-0.3829	0.67649	-0.6893	0.749577	0.077068	-0.5248	0.83038	-0.081264	0.90584	-0.2951	0.56287	0.16119	0.6774694	0.2275	-0.0621	-0.5795691	-0.2706	-0.2666	-0.592301659	-0.4657
Silicaflaq.	0.66716166	0.6981235	-0.8545845	-0.6917	-0.6053	-0.3568	-0.0396	-0.0017	-0.057	-0.2104	0.82221	0.34625368	0.07955	0.32366	0.08659	-0.2052	0.85219	-0.01355	-0.45242	0.77932	-0.5469	-0.394713	-0.25	-0.36	-0.2129	0.67134	0.1604114	0.26093	-0.4528	0.3004423	0.3191	0.00897	1	-0.3614
nanaflaqel.	-0.5056689	0.44842142	-0.1544649	-0.5228	-0.6706	-0.523	-0.6575	-0.8069	-0.9117	-0.7236	0.29765	-0.5507433	-0.004	-0.0584	-0.2329	0.51137	-0.0215	0.748614	0.229281	-0.3959	0.32889	-0.671827	0.85069	-0.6027	0.46775	0.55528	0.8392798	0.80305	-0.4531	-0.1165775	-0.3083	-0.4438	-0.067268845	-0.8989

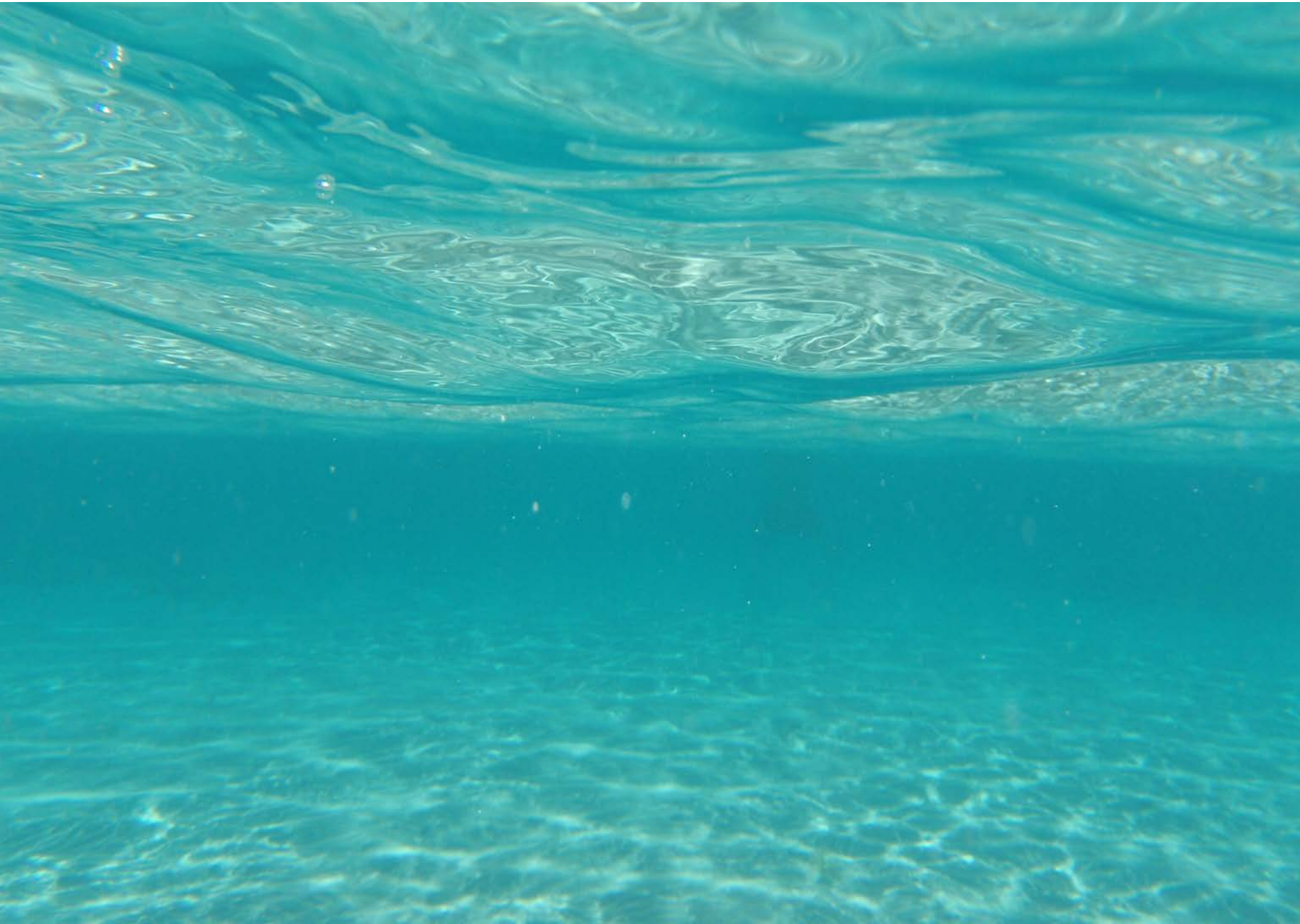
ASOCIACIJSKE MREŽE

ASOCIACIJSKE MREŽE



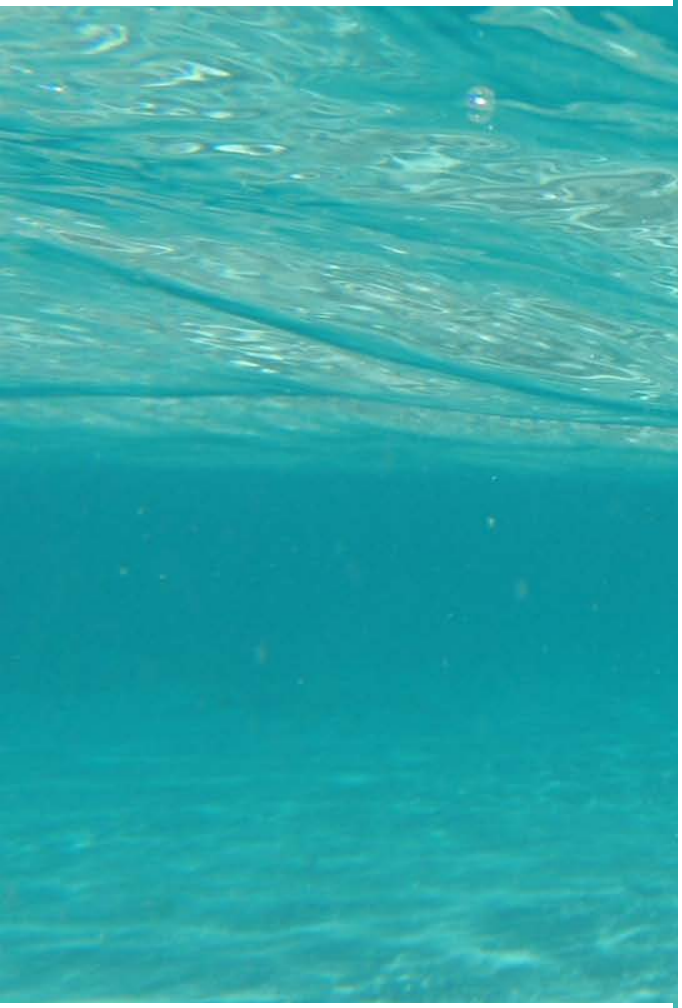
Cytoscape
Network Data Integration, Analysis, and Visualization in a Box

DINAMIKA BAKTERIJSKE ZDRUŽBE V VODNEM STOLPCU



DINAMIKA BAKTERIJSKE ZDRUŽBE V VODNEM STOLPCU

POVRŠJE



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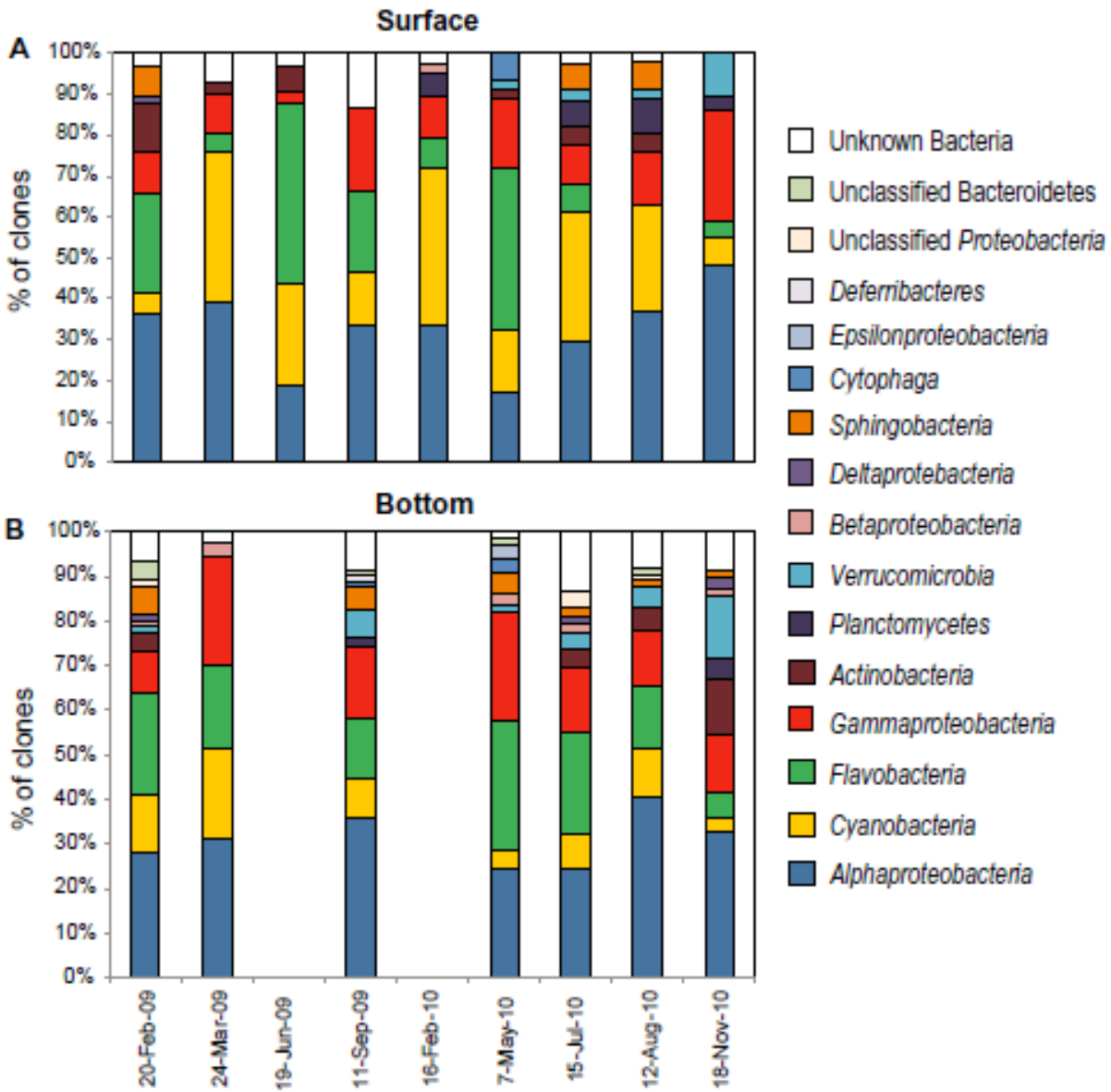
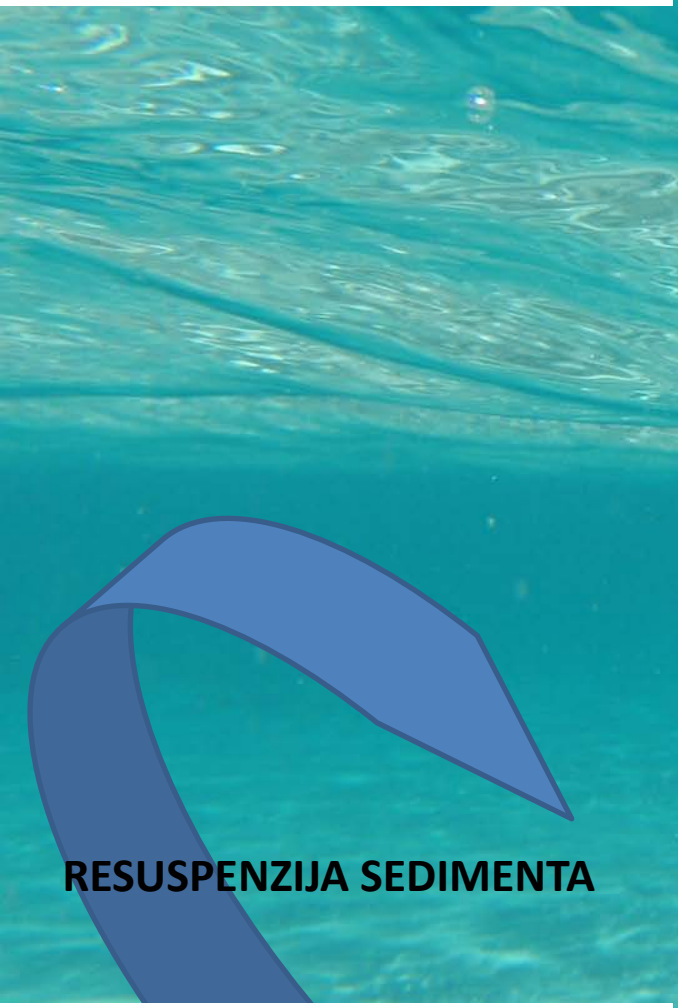


DINAMIKA BAKTERIJSKE ZDRUŽBE V VODNEM STOLPCU

POVRŠJE



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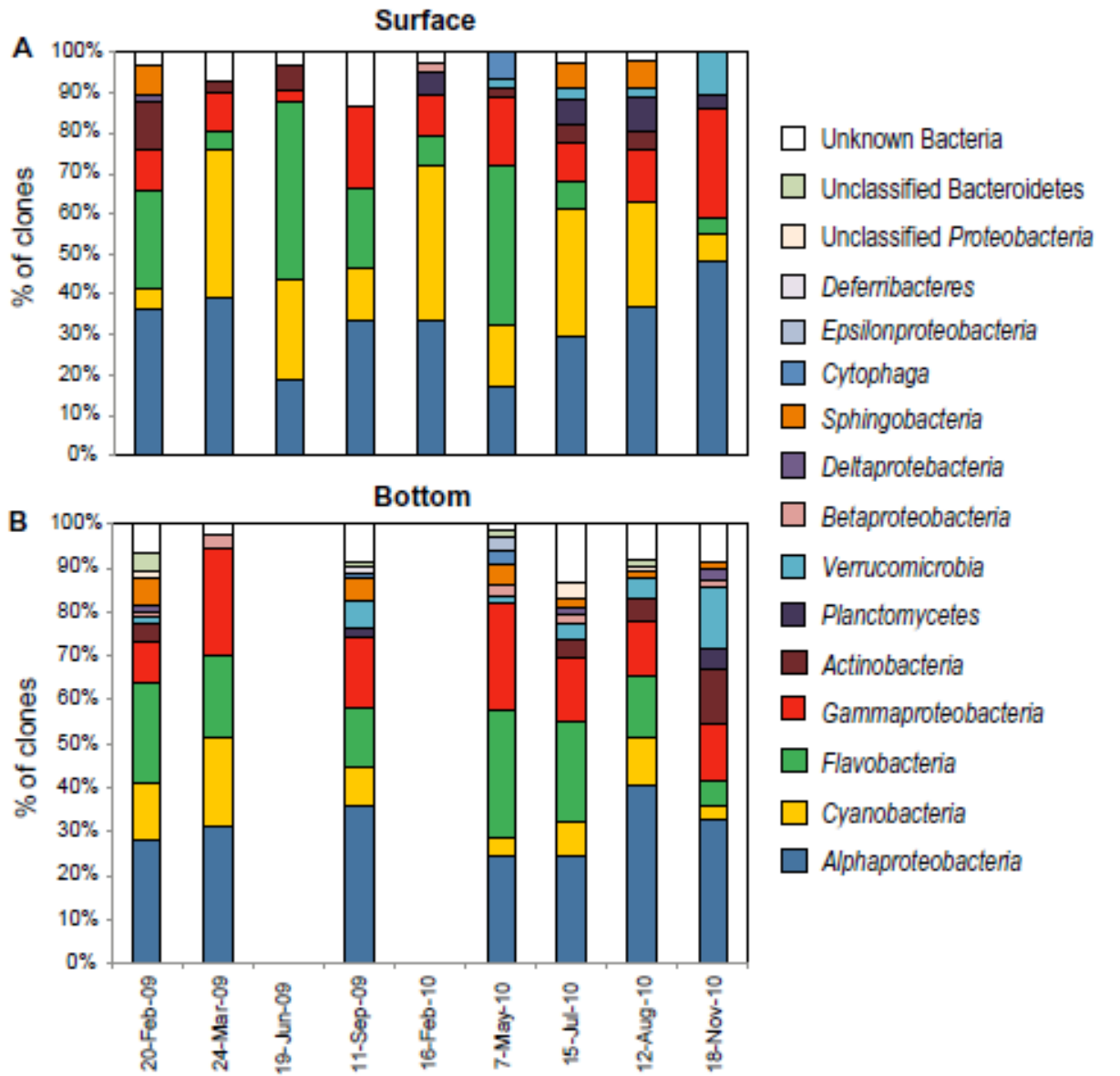


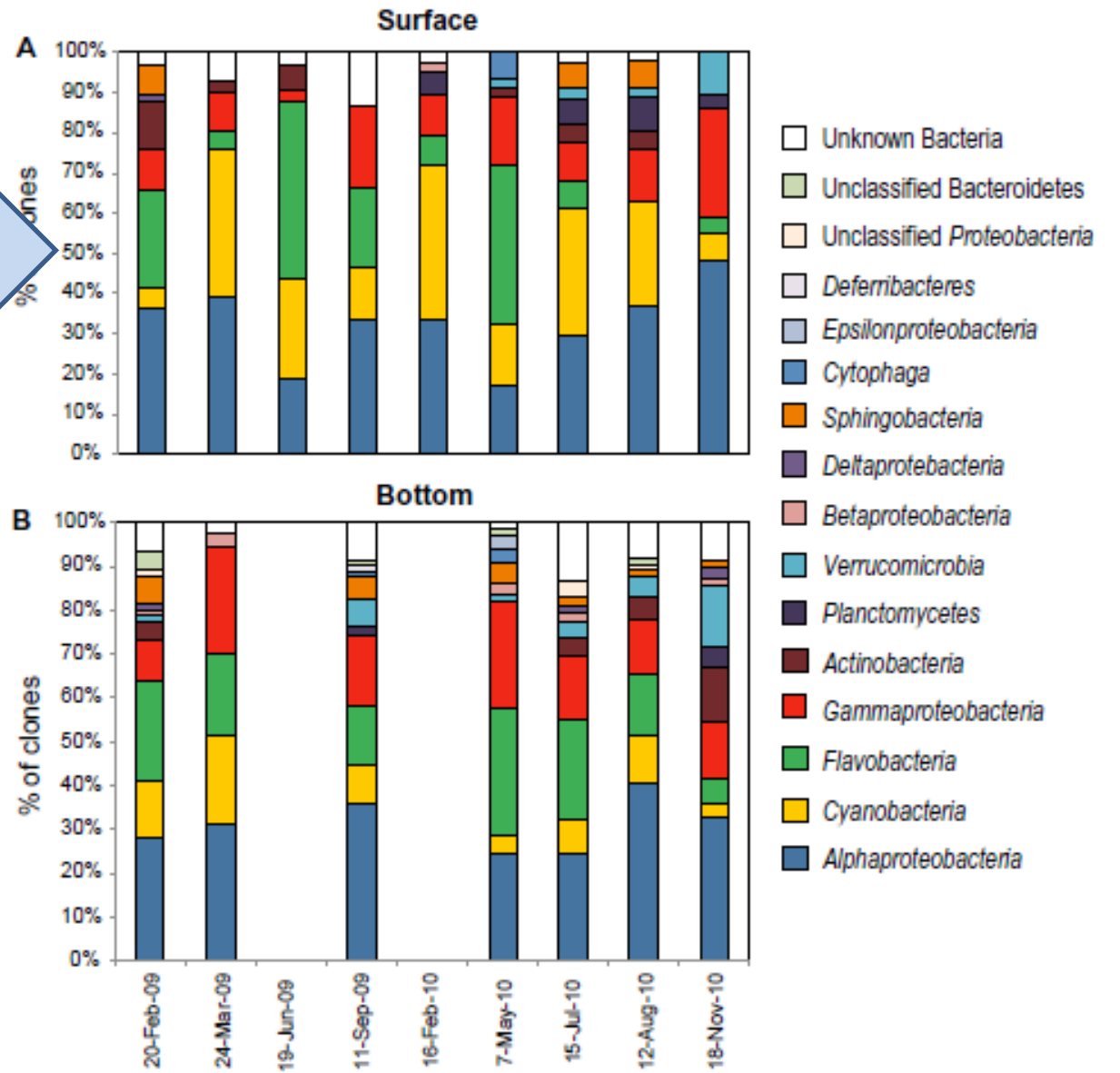
DINAMIKA BAKTERIJSKE ZDRUŽBE V VODNEM STOLPCU

POVRŠJE

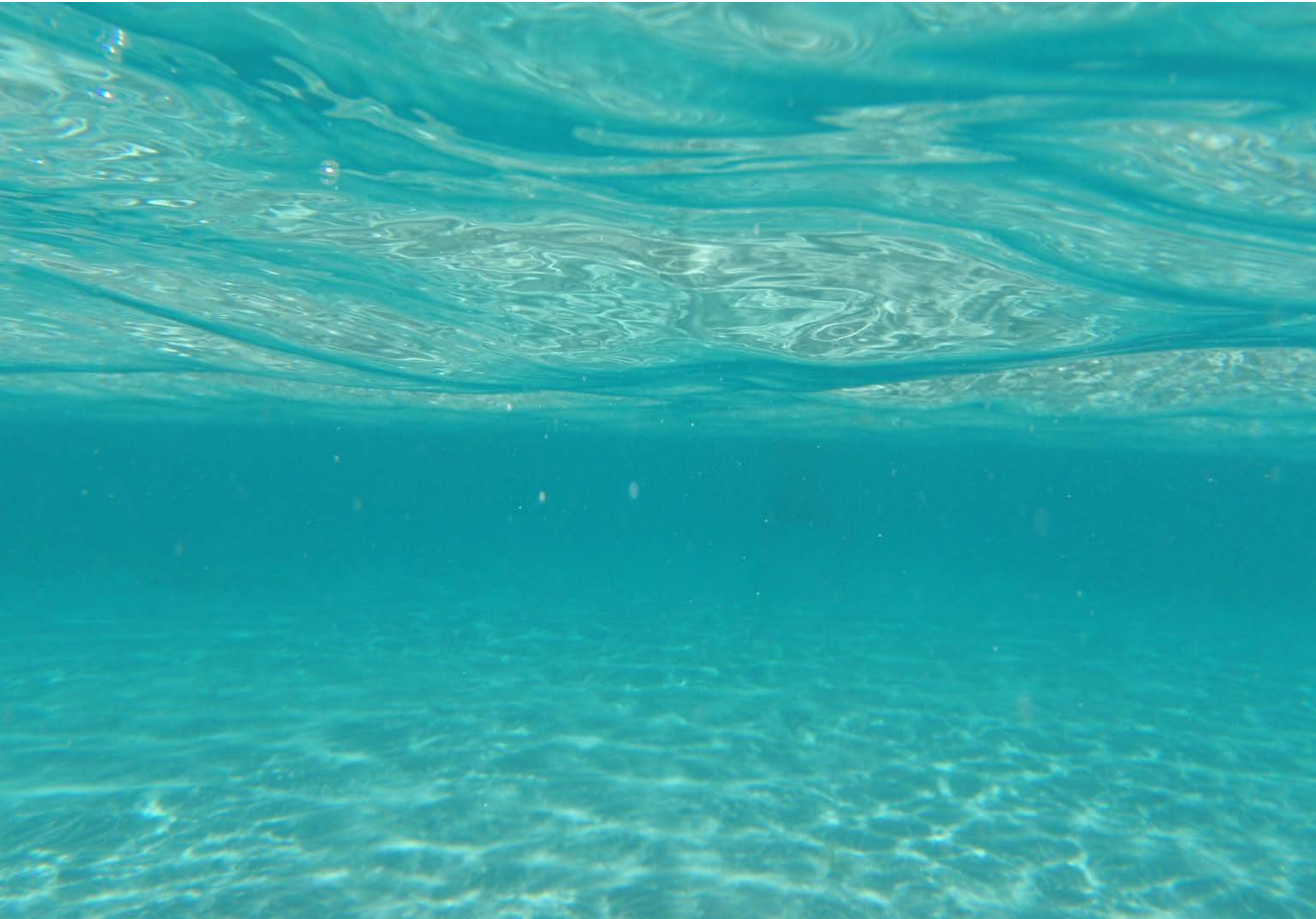
- Temperaturna nihanja
- Rečni vnosi (slanost, hranila)

RESUSPENZIJA SEDIMENTA

DNO



TEMPERATURA



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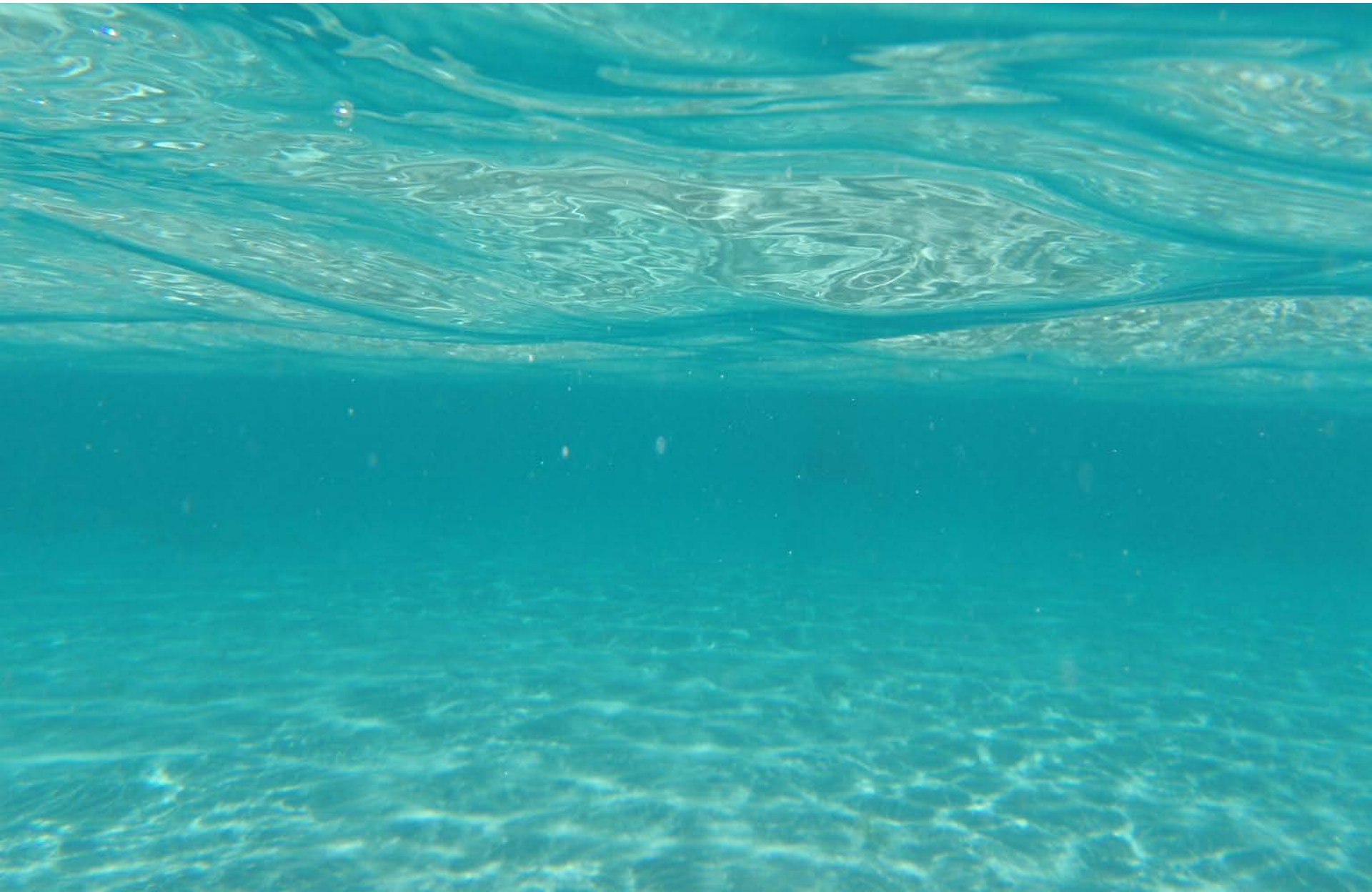
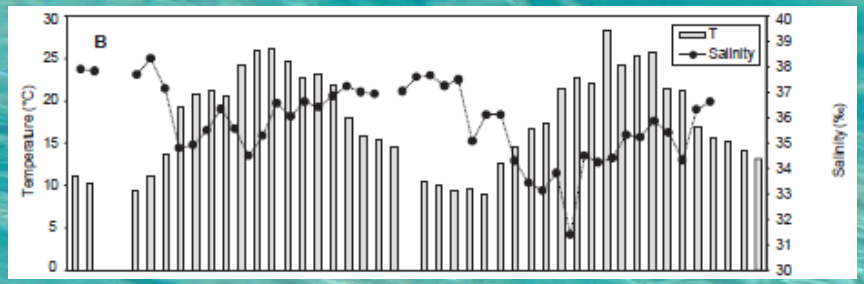
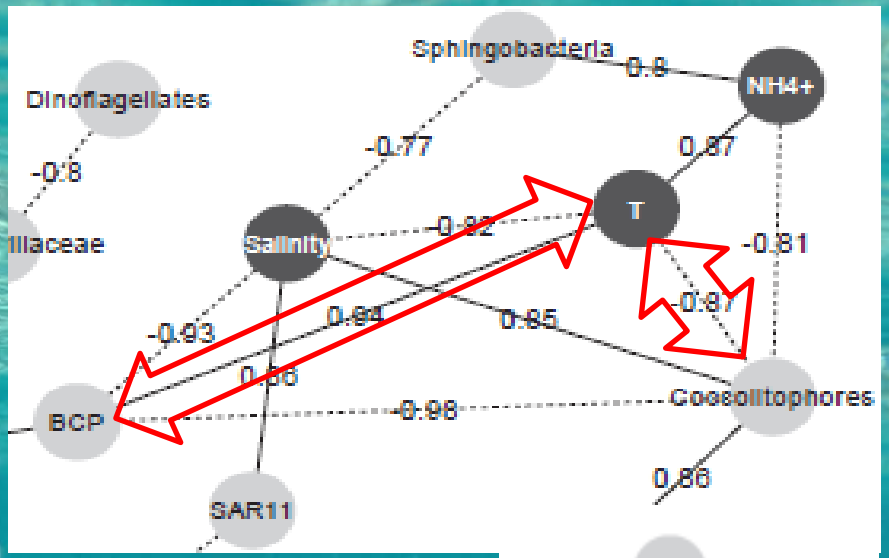
VPLIVA NA PRODUKTIVNOST BAKTERIJSKE ZDRUŽBE NA POVRŠJU

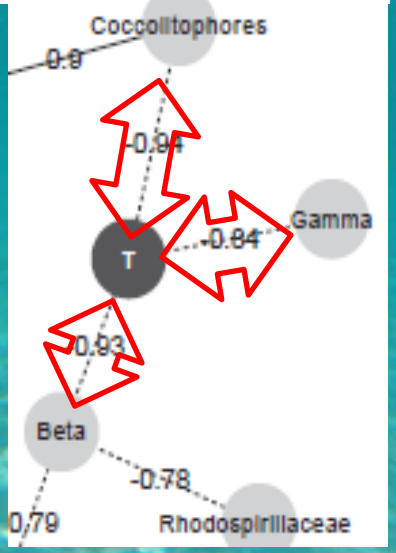


TEMPERATURA

VPLIVA NA PRODUKTIVNOST BAKTERIJSKE ZDRUŽBE NA POVRŠJU







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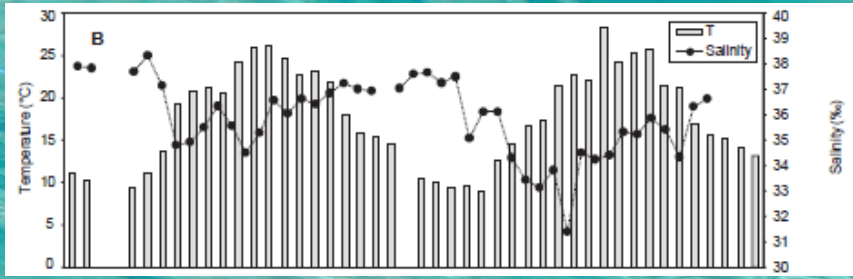

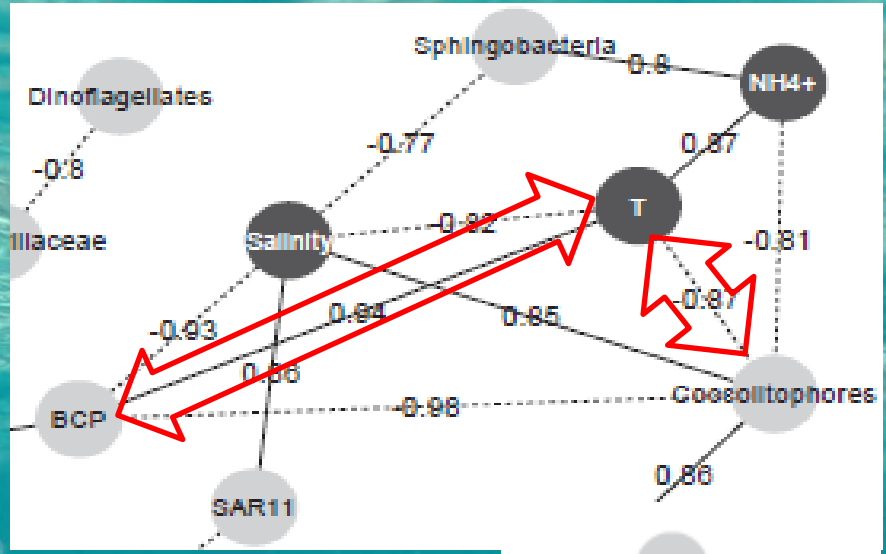

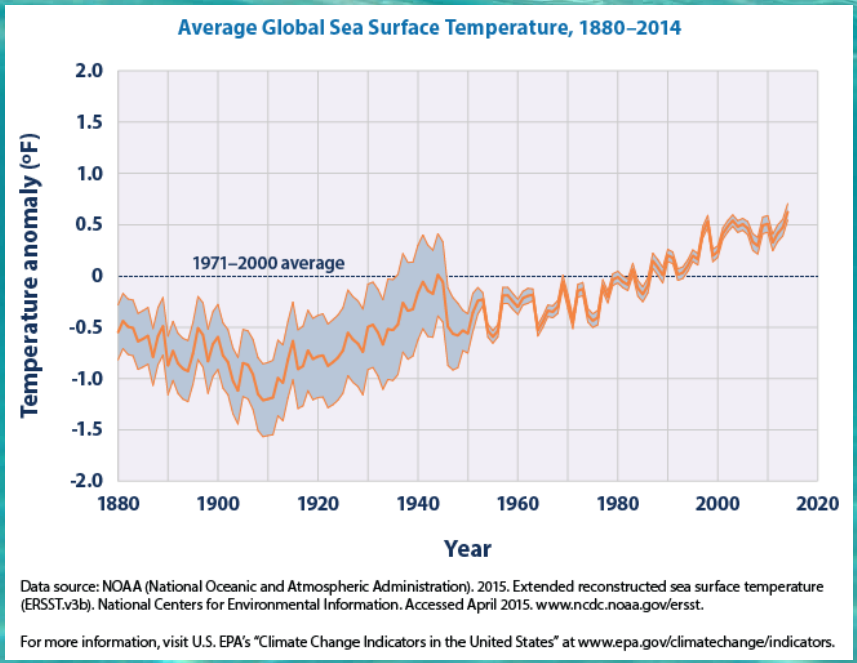

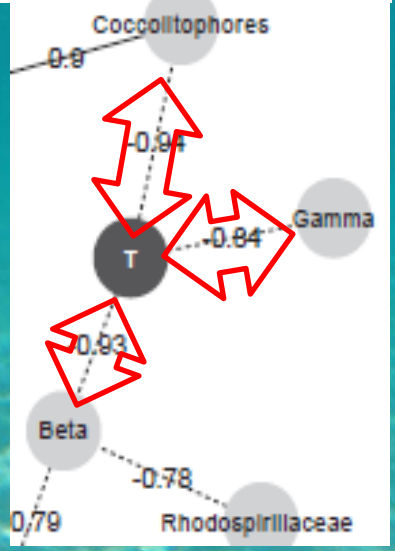

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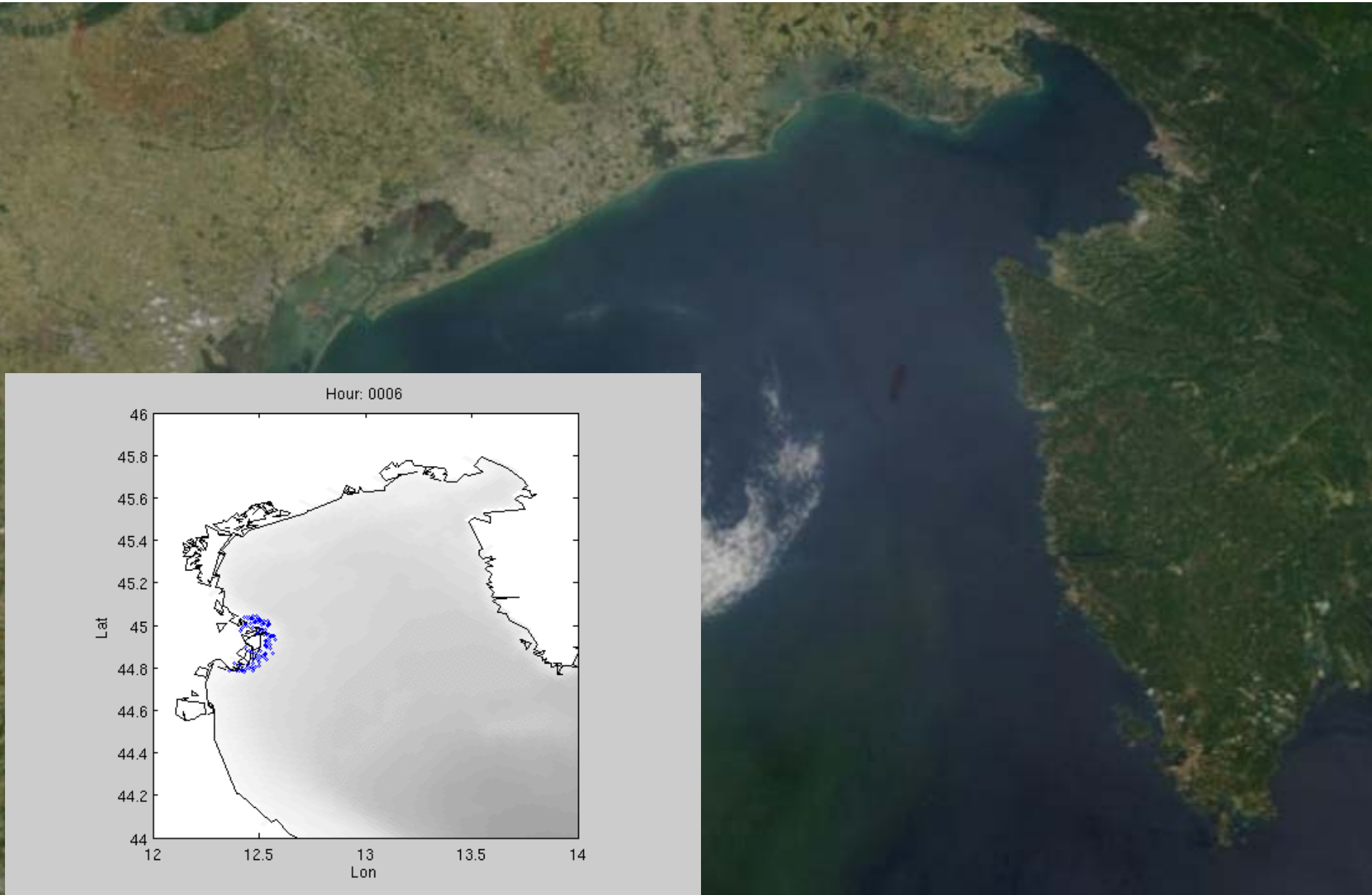

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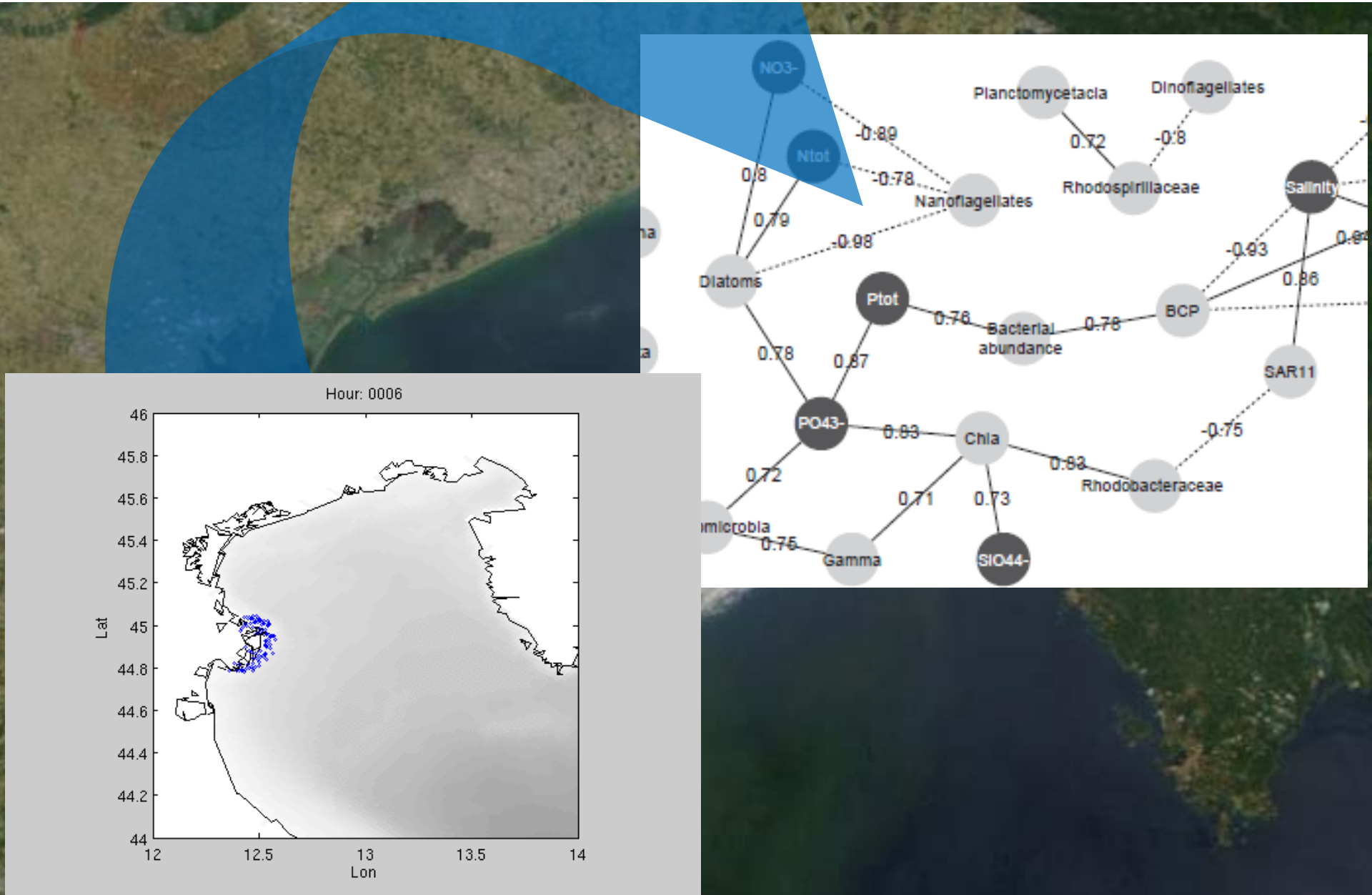

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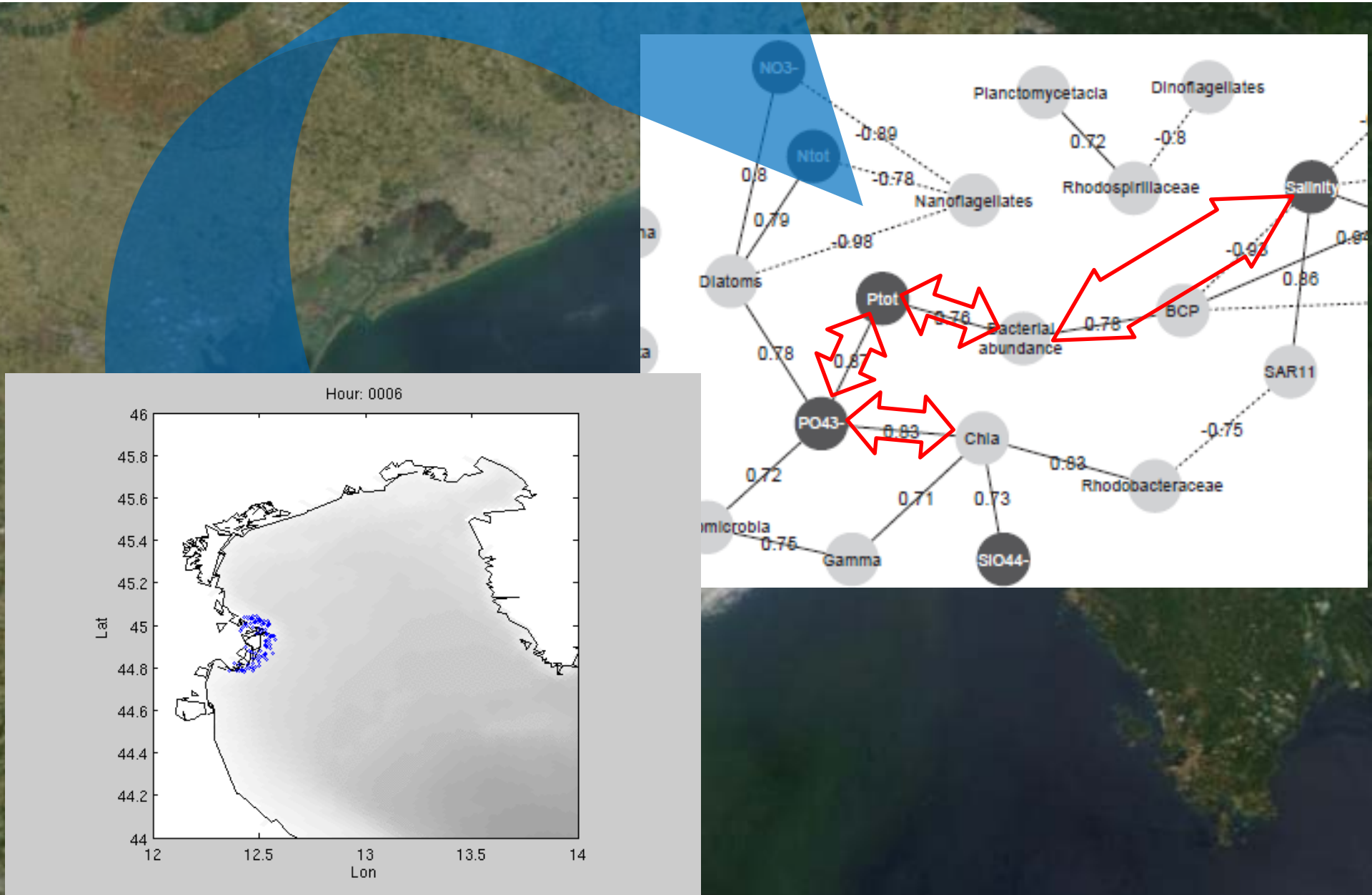

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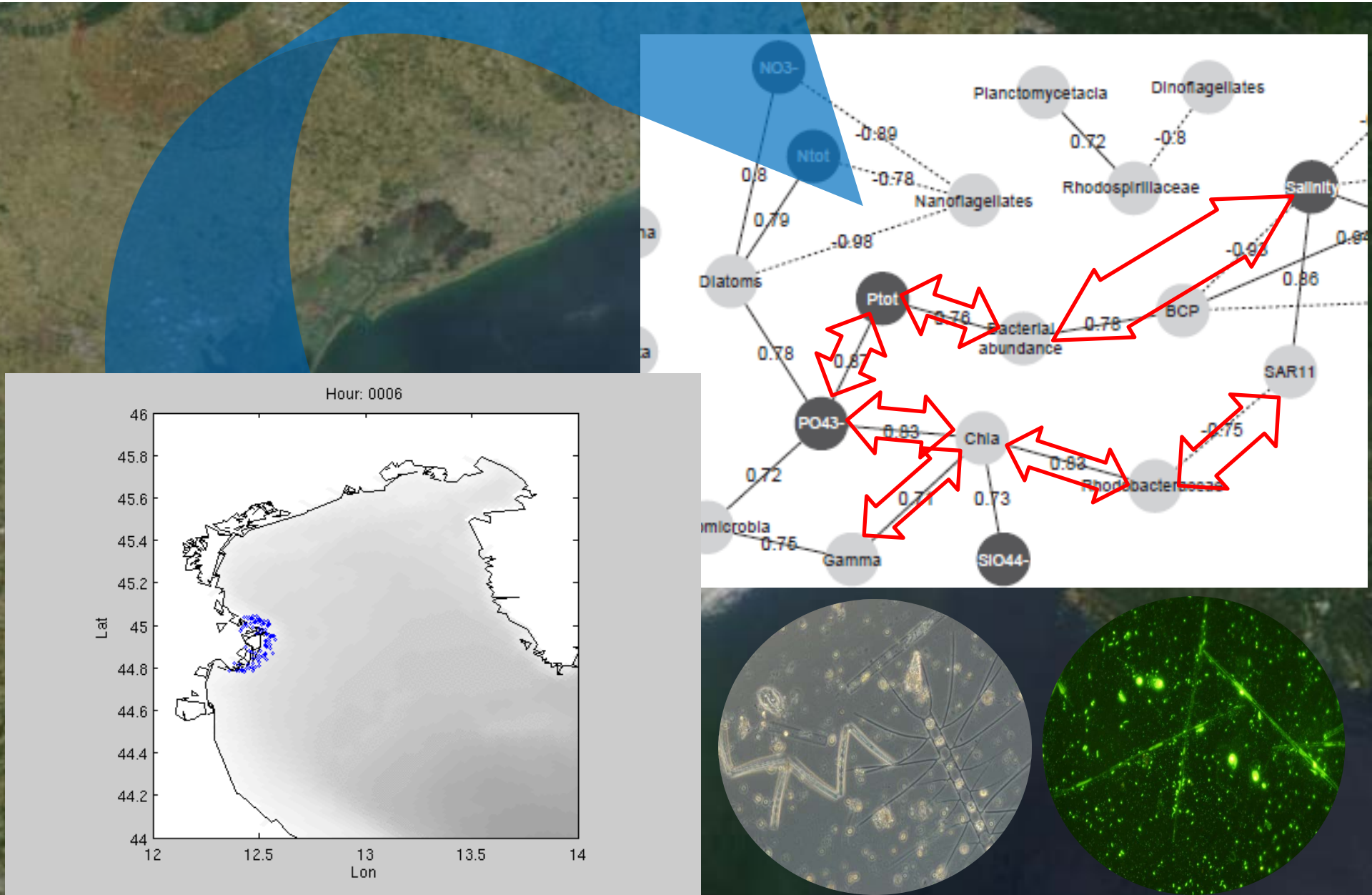

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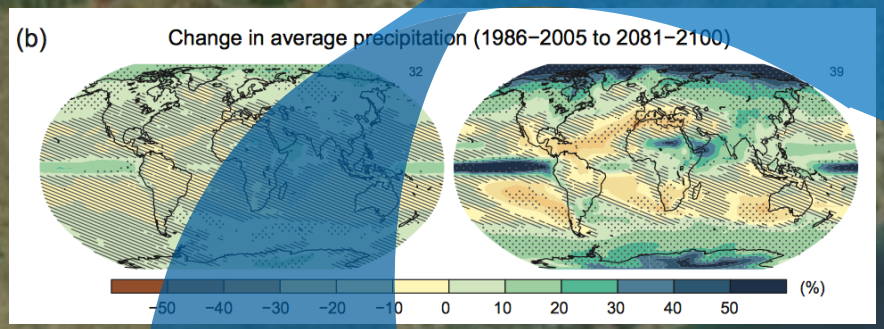

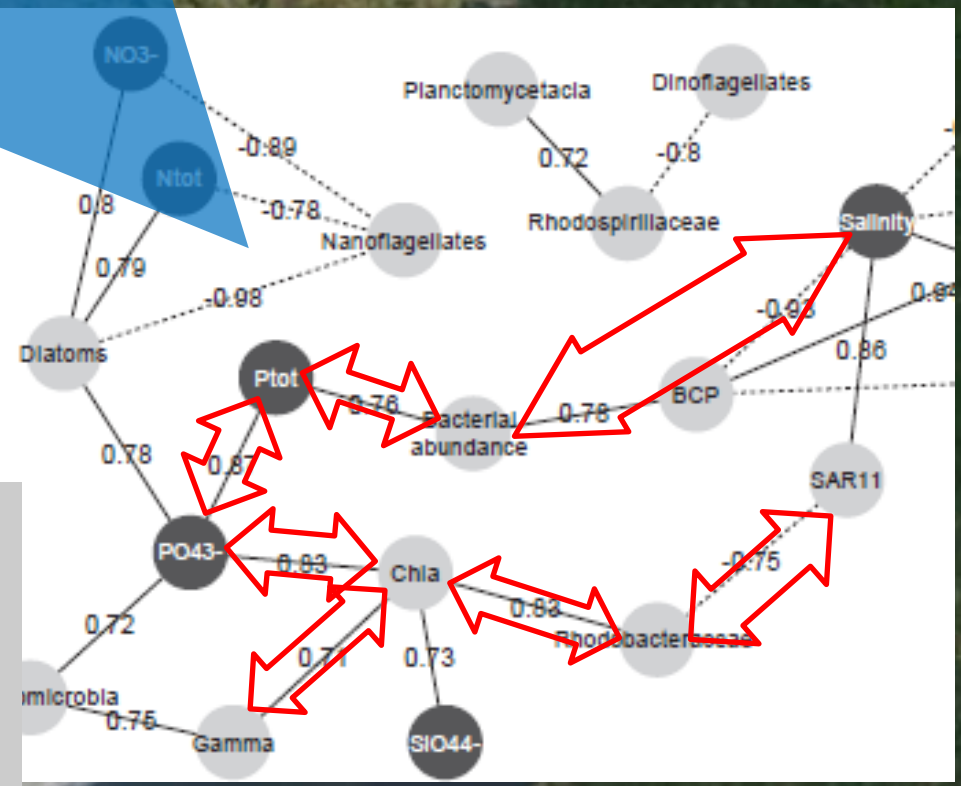

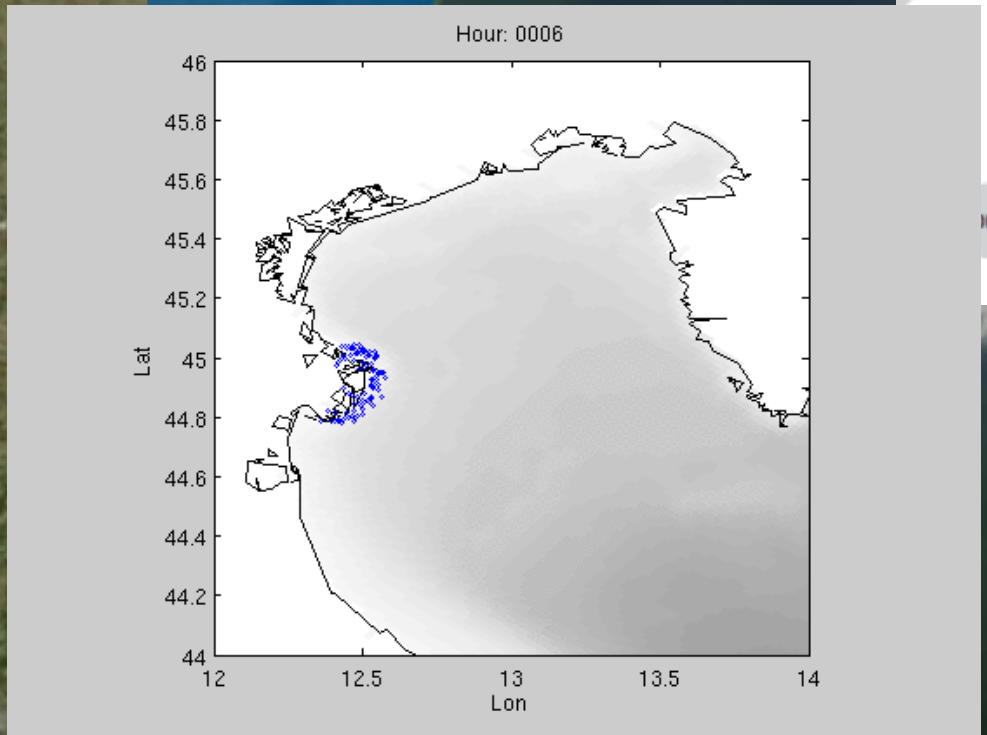

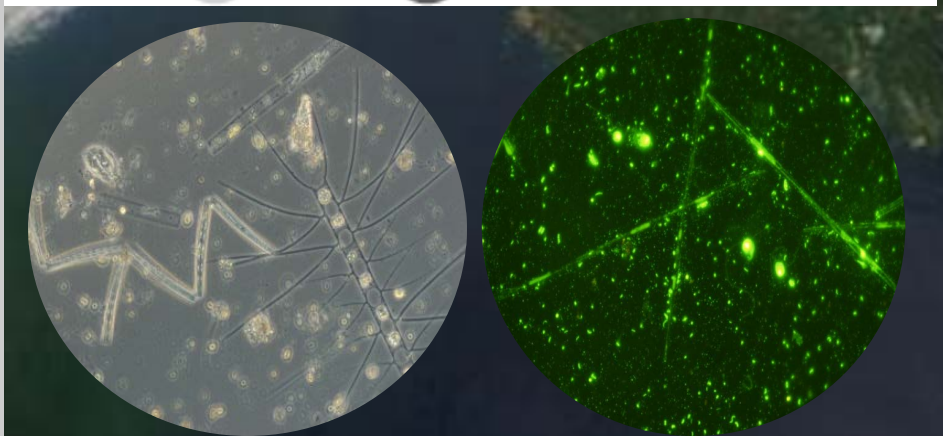

environmental microbiology

Environmental Microbiology (2014) doi:10.1111/1462-2920.12519

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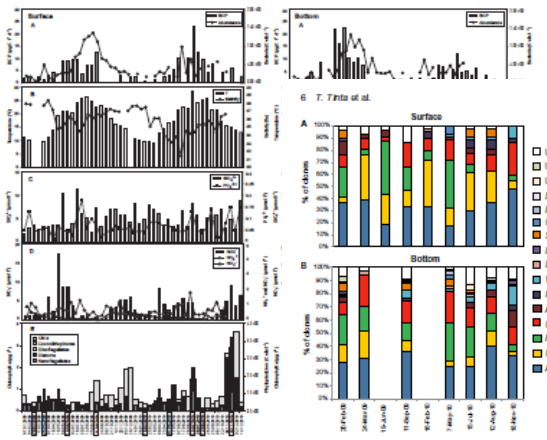

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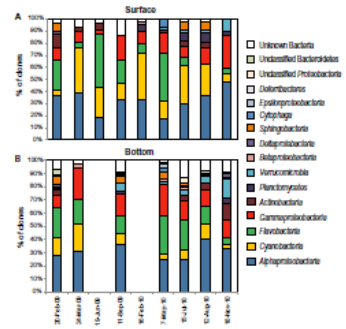

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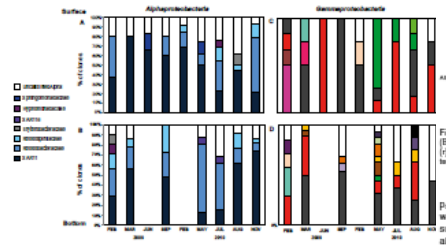

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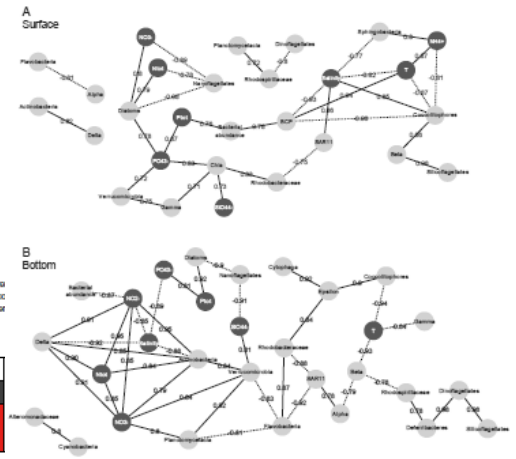

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Discussion

Knowing how the variability of environmental factors structures the microbial community contributes to our ability to predict the response of the ecosystem to natural and anthropogenic pressures. In the semi-enclosed coastal ecosystem of the Gulf of Trieste, despite the shallowness of the studied area (< 25 m depth), a significant difference in microbial community structure between the surface and the bottom layer was observed (Figs 3–5, Supporting Information Fig. S6, Supporting Information

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1. Dolgoročen niz podatkov

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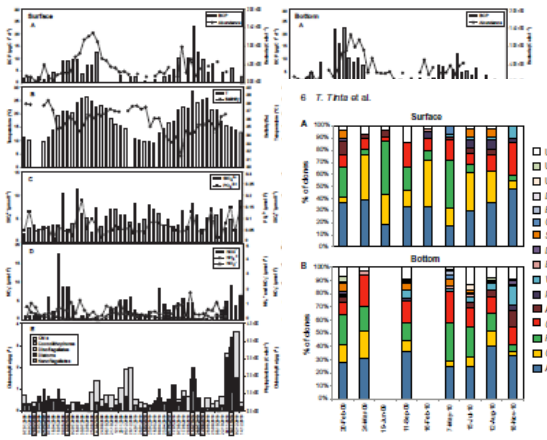

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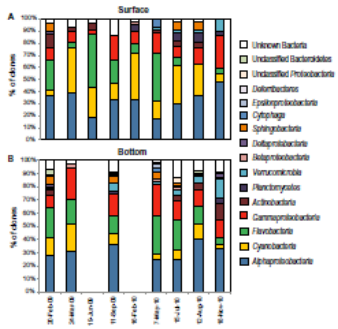

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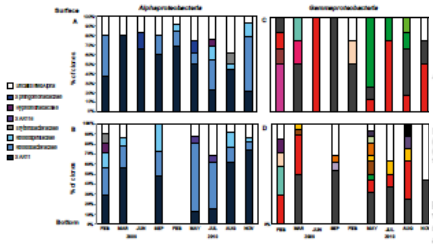

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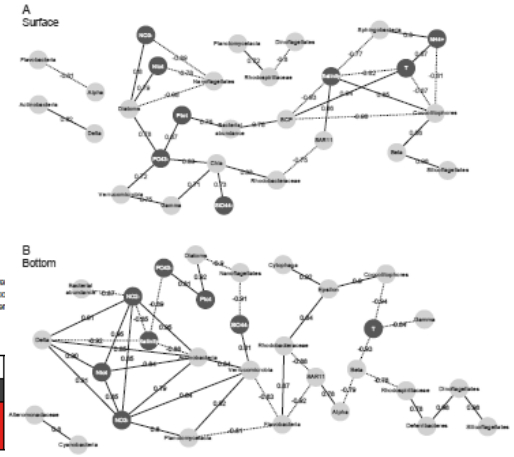

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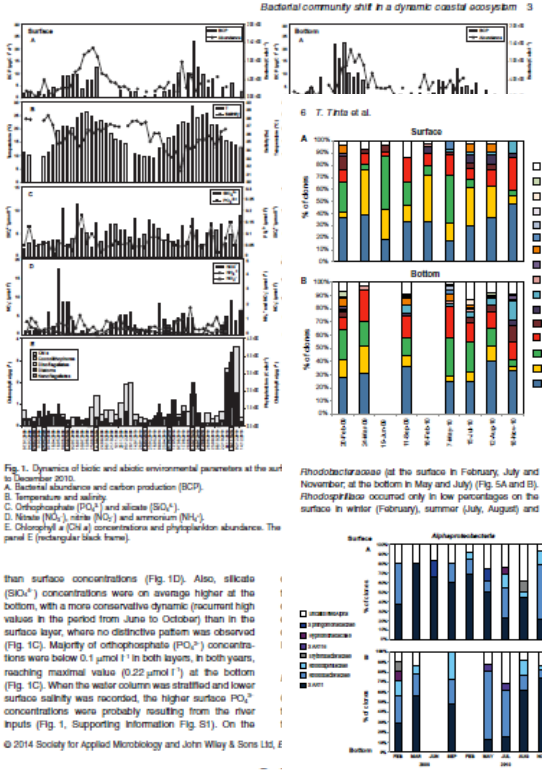

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than surface concentrations (Fig. 1D). Also, silicate (SiO_4^{4-}) concentrations were on average higher at the bottom, with a more conservative dynamic (recurrent high values in the period from June to October) than in the surface layer, where no distinctive pattern was observed (Fig. 1C). Majority of orthophosphate (PO_4^{3-}) concentrations were below 0.1 μmol l^{-1} in both layers, in both years, reaching maximal value (0.22 μmol l^{-1}) at the bottom (Fig. 1C). When the water column was stratified and lower surface salinity was recorded, the higher surface PO_4^{3-} concentrations were probably resulting from the river inputs (Fig. 1, Supporting Information Fig. S1). On the

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Fig. 4. Composition of 16S rRNA gene bacterial clone libraries (% of clones). The clone libraries were constructed from samples collected simultaneously at the surface (5 m, A) and at the bottom (20 m, B).

Rhodobacteraceae (at the surface in February, July and November; at the bottom in May and July) (Fig. 5A and B). *Rhodospirillace* occurred only in low percentages on the surface in winter (February), summer (July, August) and autumn (November) libraries. They we the bottom, with the highest values rec nuary) and late summer (August–Septer porting Information Table S2).

Fig. 5. Dynamic of bacterial families within Alphaproteobacteria (A, B) and Gammaproteobacterial class (C, D) at the su bottom (B, D).

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Fig. 6. Association networks showing significant correlations ($r \geq 0.6$, $p_c < 0.007$, $q < 0.1$) among variables at the surface (A) and at the bottom (B). The light grey nodes represent biotic parameters, whereas the dark grey nodes represent abiotic parameters. The correlations coefficients (r) are labelled on connecting lines. Positive correlation – solid line; negative correlation – dashed line. BCP, bacterial carbon production; T, temperature; Ntot, total nitrogen; NO_3^-, nitrate; NO_2^-, nitrite; NH_4^+, ammonium; Ptot, total phosphorous; PO_4^{3-}, orthophosphate; SiO_4^{4-}, silicate.

$p_c < 0.0005$). *Gammaproteobacteria* positively correlated with a rare community member *Verrucomicrobia* at the surface ($r = 0.75$, $p_c < 0.003$). At the surface, there was also a positive correlation between rare bacterial community members *Actinobacteria* and *Deltaproteobacteria* ($r = 0.82$, $p_c < 0.0005$), and between *Rhodospirillaceae* and *Planctomycetes* ($r = 0.72$, $p_c < 0.007$, Fig. 6A). The rare community members *Deltaproteobacteria*, *Actinobacteria*, *Verrucomicrobia* and *Planctomycetes* positively correlated also at the bottom ($r \geq 0.8$, $p_c < 0.002$, Fig. 6B).

Discussion

Knowing how the variability of environmental factors structures the microbial community contributes to our ability to predict the response of the ecosystem to natural and anthropogenic pressures. In the semi-enclosed coastal ecosystem of the Gulf of Trieste, despite the shallowness of the studied area (< 25 m depth), a significant difference in microbial community structure between the surface and the bottom layer was observed (Figs 3–5, Supporting Information Fig. S6, Supporting Information

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Bacterial community shift is induced by dynamic environmental parameters in a changing coastal ecosystem (northern Adriatic, northeastern Mediterranean Sea) – a 2-year time-series study

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Summary

The potential link between the microbial dynamics and the environmental parameters was investigated in a semi-enclosed and highly dynamic coastal system (Gulf of Trieste, northern Adriatic Sea, NE Mediterranean Sea). Our comprehensive 2-year time-series study showed that despite the shallowness of this area, there was a significant difference between the surface and the bottom bacterial community structure. The bottom bacterial community was more diverse than the surface one and influenced by sediment re-suspension. The surface seawater temperature had a profound effect on bacterial productivity, while the bacterial community structure was more affected by freshwater-borne nutrients and phytoplankton blooms. Phytoplankton blooms caused an increase of *Gammaproteobacteria* (*Alteromonadaceae*, SAR86 and *Vibrionaceae*) and shift in dominance from SAR11 to *Rhodobacteraceae* taxon at the surface. Our results propose the importance of the water mass movements as drivers of freshwater-borne nutrients and of allochthonous microbial taxa. This study emphasizes the prediction power based on association networks analyses that are fed with long-term measurements of microbial and environmental parameters. These interaction maps offer valuable insights into the response of marine ecosystem to climate- and anthropogenic-driven stressors.

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Introduction

The dynamic costal marine ecosystems represent ideal systems for studying the responses of bacterial commu-
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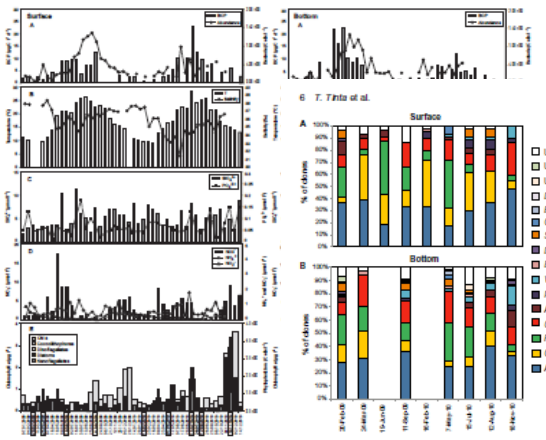

Fig. 1. Dynamics of biotic and abiotic environmental parameters at the surf to December 2010.
A. Bacterial abundance and carbon production (BCP).
B. Temperature and salinity.
C. Orthophosphate (PO_4^{3-}) and silicate (SiO_4^{4-}).
D. Nitrate (NO_3^-), nitrite (NO_2^-) and ammonium (NH_4^+).
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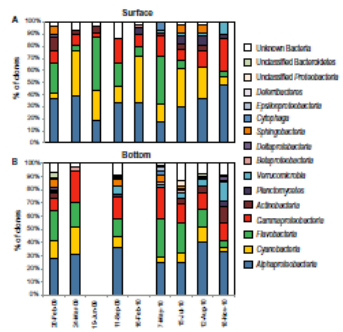

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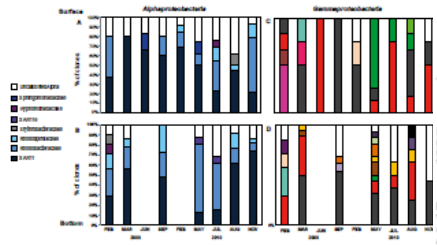

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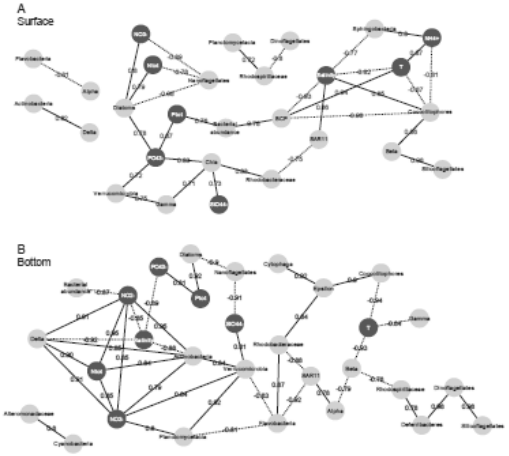

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