Monitoring of Agrochemicals within the Mesoamerican Reef (MAR)

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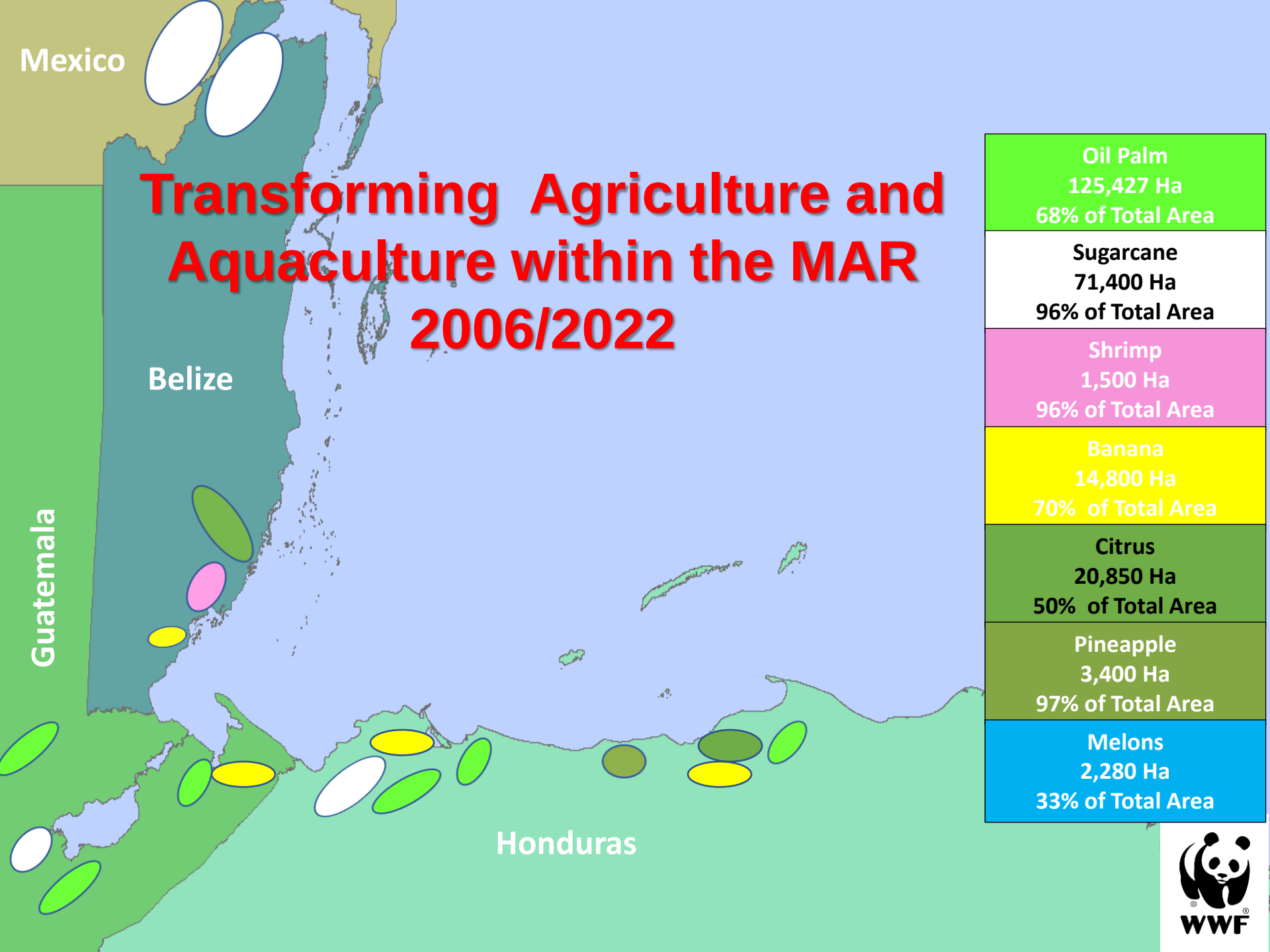
Findings: 2004-2022

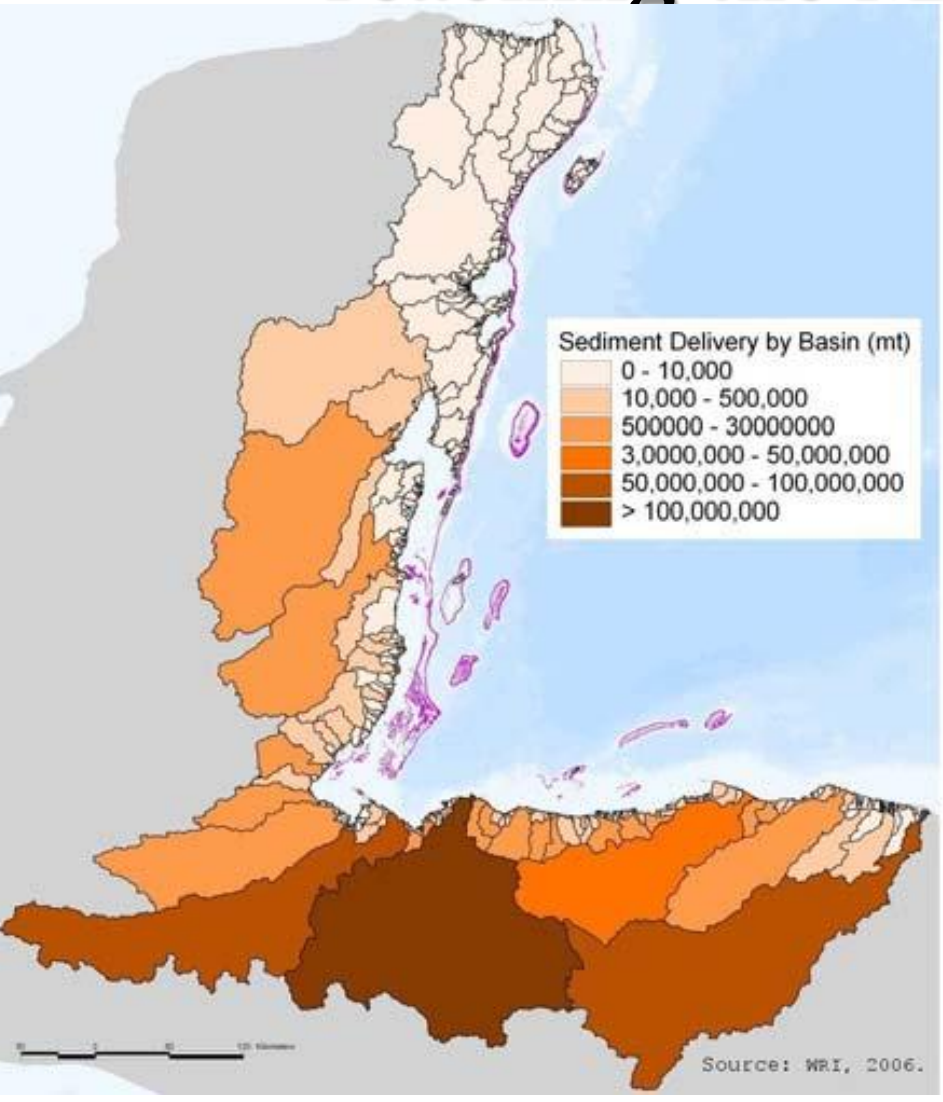
Mauricio Mejia
WWF Mesoamerica

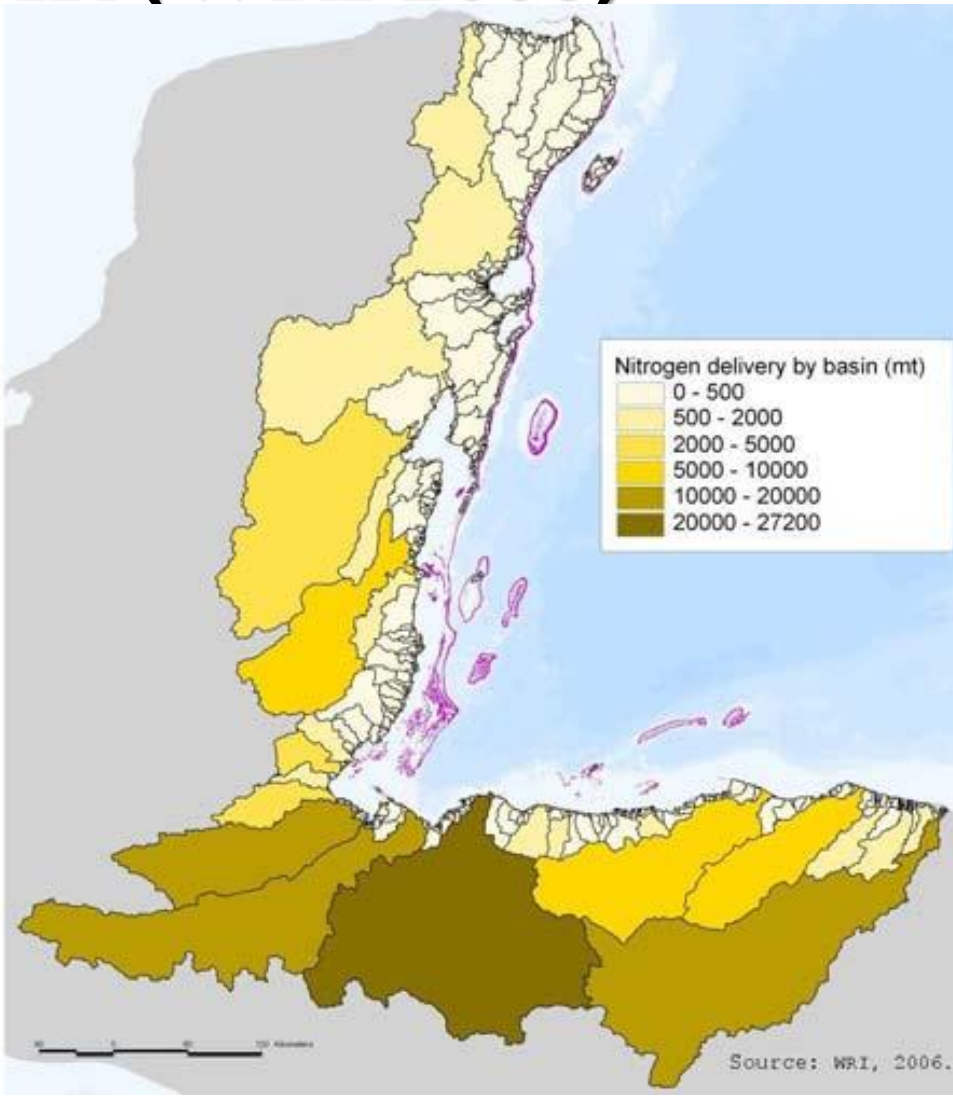
2004 - Effluent Pollution #1 Threat!

Threats to the MAR	CRITERIA							
	Area	Severity	Urgency	Sub-total	WWF Niche	Opportunity to act	Sub-total	Total
Effluent pollution	9	9	9	27	11	11	22	49
Unsustainable fishing	10	8	8	26	10	10	20	46
Climate Change	11	11	10	32	8	3	13	45
Habitat destruction for new construction	7	10	11	28	9	7	16	44
Poor soil management	6	7	7	20	7	9	16	36
Recreational activities	3	6	4	13	6	8	14	27
Maritime transport (commercial and recreational)	4	5	5	14	3	1	4	18
Solid waste	5	3	6	14	1	2	3	17
Freshwater extraction	2	4	2	8	5	4	9	17
Invasive species and disease	8	1	3	12	2	3	5	17

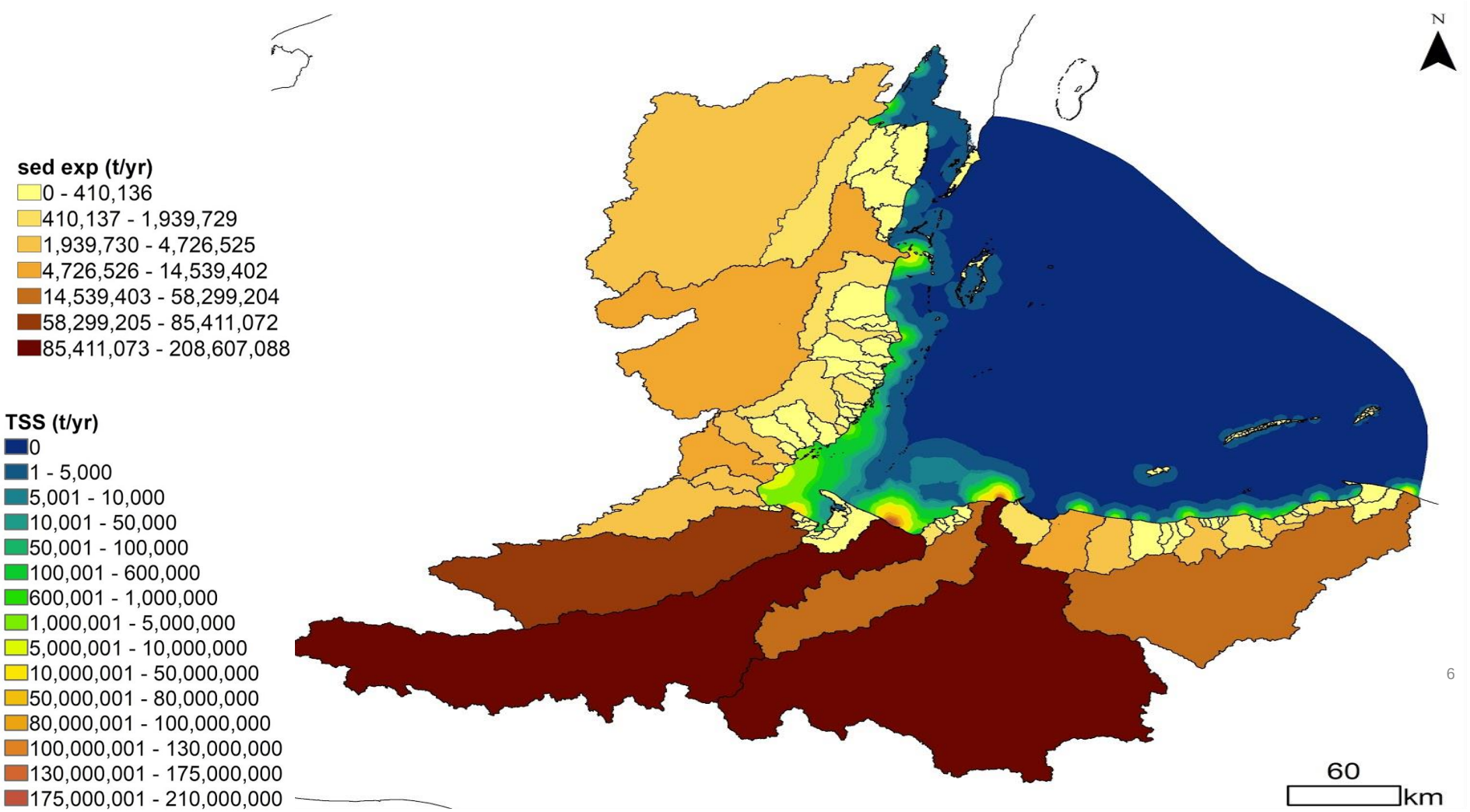

Mexico
Belize
Guatemala
Honduras
Transforming Agriculture and Aquaculture within the MAR 2006/2022
Oil Palm
125,427 Ha
68% of Total Area
Sugarcane
71,400 Ha
96% of Total Area
Shrimp
1,500 Ha
96% of Total Area
Banana
14,800 Ha
70% of Total Area
Citrus
20,850 Ha
50% of Total Area
Pineapple
3,400 Ha
97% of Total Area
Melons
2,280 Ha
33% of Total Area
WWF

The origin of sediments and nutrients reaching the MAR (WRI 2006)



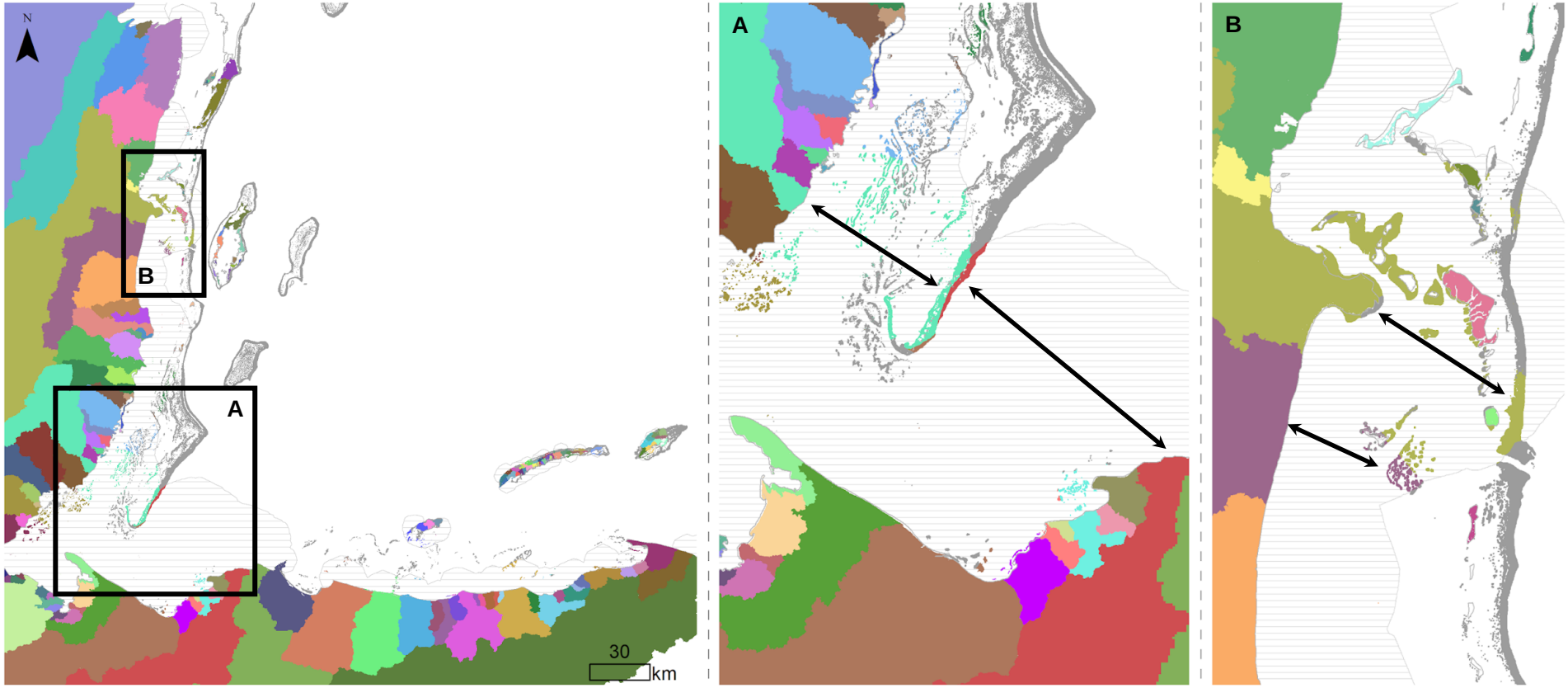


Baseline results: (IKI 2020)



IKI SMART COAST MAR Project

Ex: Watersheds driving changes in coral reef resilience through sediment export



Bio Accumulation Assessments

Sampling sites by Year
BELIZE

Sites	2004	2007	2013	2019	2022
Sapodilla Cayes – Bz	X	X	X		X
Turneffe – Bz		X	X		X
Monkey River – Bz		X	X		X
New River - Bz					X

Sampling sites by Year
HONDURAS

Sites	2004	2007	2013	2019	2022
Barbaretta – Hn		X	X	X	
Cayos Cochinos – Hn		X	X	X	
Ulua River – Hn		X	X	X	
Motagua River – Hn		X			
Utila – Hn		X			
Chamelecon River - Hn				X	

Sampled Organisms

Organisms	2004	2007	2013	2019	2022
Conch (*Strombus gigas*)	X	X	X	X	X
Coral (*Porites astreoides*)	X	X	X	X	X
White grunt (*Haemulon plumieri*)	X	X	X	X	X
River mouths sediments		X	X	X	X
Marine sedimennts		X	X	X	X

Sampled Organisms

Organisms	2004	2007	2013	2019	2022
Mangrove Oyster (*Isognomon alatus*)	X	X			
Seagrass (*T halassi* a)	X				
Penshell clam (*Pinna camea*)	X				
Cucumber (*Holothuria mexicana*)	X				
Sponge (*Spheciospongia vesparium*)	X				
Dog snapper (*Lutjanus jocu*)	X				
Baracuda (*Sphyraena barracuda*)	X				
Schoolmaster snapper (*Lutjanus apodus*)	X				

1. Bioaccumulation 2004

First Round: Lab Methods
BELIZE (BAHA) – Honduras (FHIA)

Testing of samples for the presence of Organochlorine pesticides on invertebrate and plant samples:

- 10 of 13 agrochemicals were found in tested samples.
- Detected agrochemicals corresponds to Insecticides and Fungicides.

Pesticides detected - 2004	Maximum ppm
Chlorothalonyl	6.3
Imidacloprid	1.0
Malathion	0.14
DDT	0.41
Mancozeb	0.15
Deltamethrin	0.09
Fipronil	0.83
Propanil	0.01
Lindane	0.04
Aldrin	0.017

2004's Meeting - Honduras

Results were reviewed by:

–WWF

– Key agricultural partners (Chiquita, Del Monte, Dole, Fyffes)

– Chemicals companies (Dow, DuPont, Syngenta)

– Other stakeholders.

2004's Meeting - Conclusions

- It was agreed that a second round must be conducted to validated the findings in 2004
- Samples must be collected following an accepted laboratory protocol.
- Haereticus Environmental Laboratories were selected for a second round of analysis
- Protocols were developed by Craig Downs-PhD

2. Bioaccumulation 2007

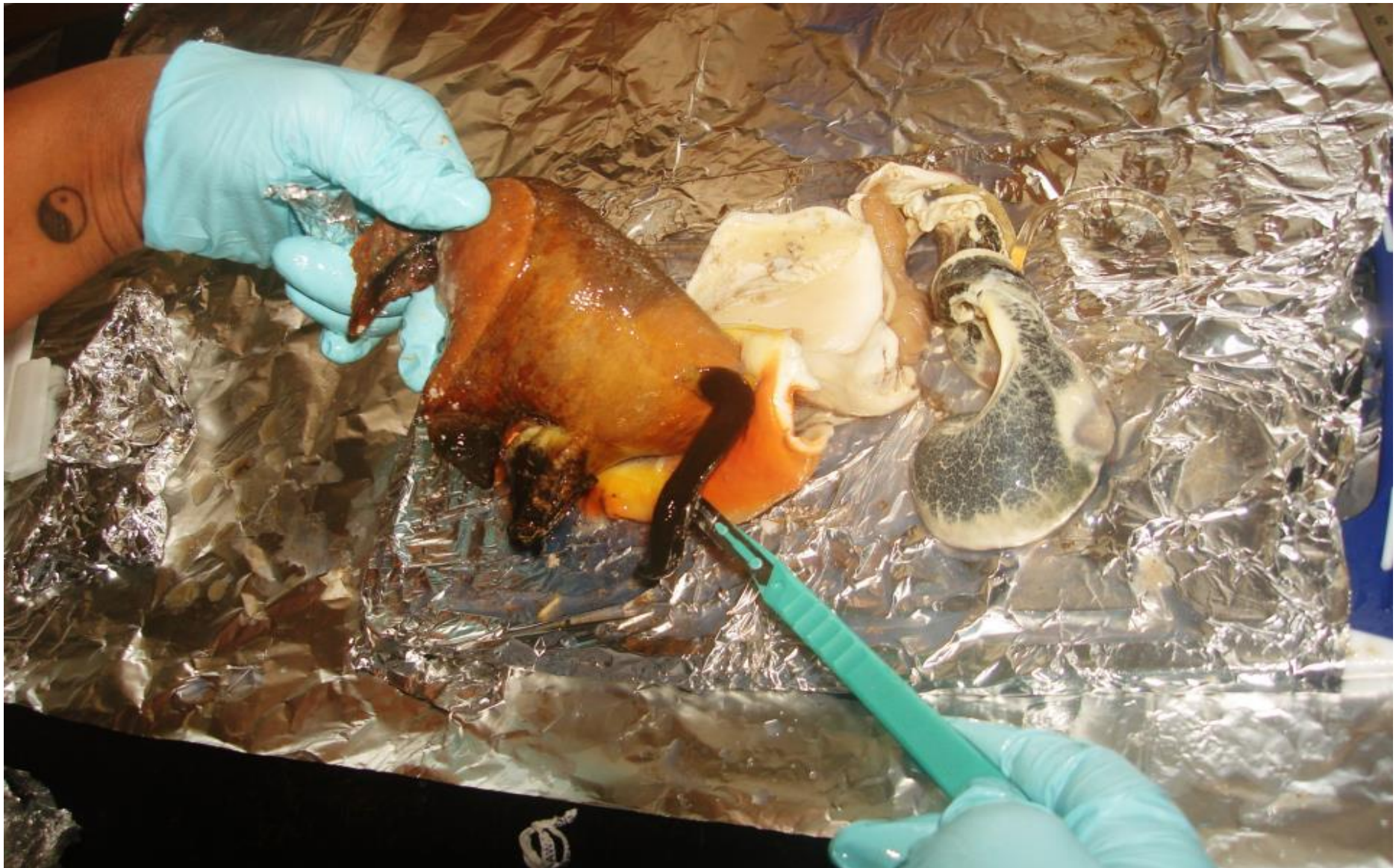
2007

- With approved protocols, a second round of sampling and analysis was conducted in 2007
- Sediments were added to the list of samples to be taken in all sites.
- The main rivers were added as sites to collect sediments.

2007's Results

- ✓ Yielded no trace of any of the 95 agrochemical compounds tested for.

3. Bioaccumulation 2013



Bioaccumulation 2013

- The third round of bio-accumulation was conducted following 2007 methodology-protocols.
- 154 samples of coral, conch, fish, and sediments - 50% sent for analysis at a US Laboratory
- Samples collected within six sites in Belize and Honduras

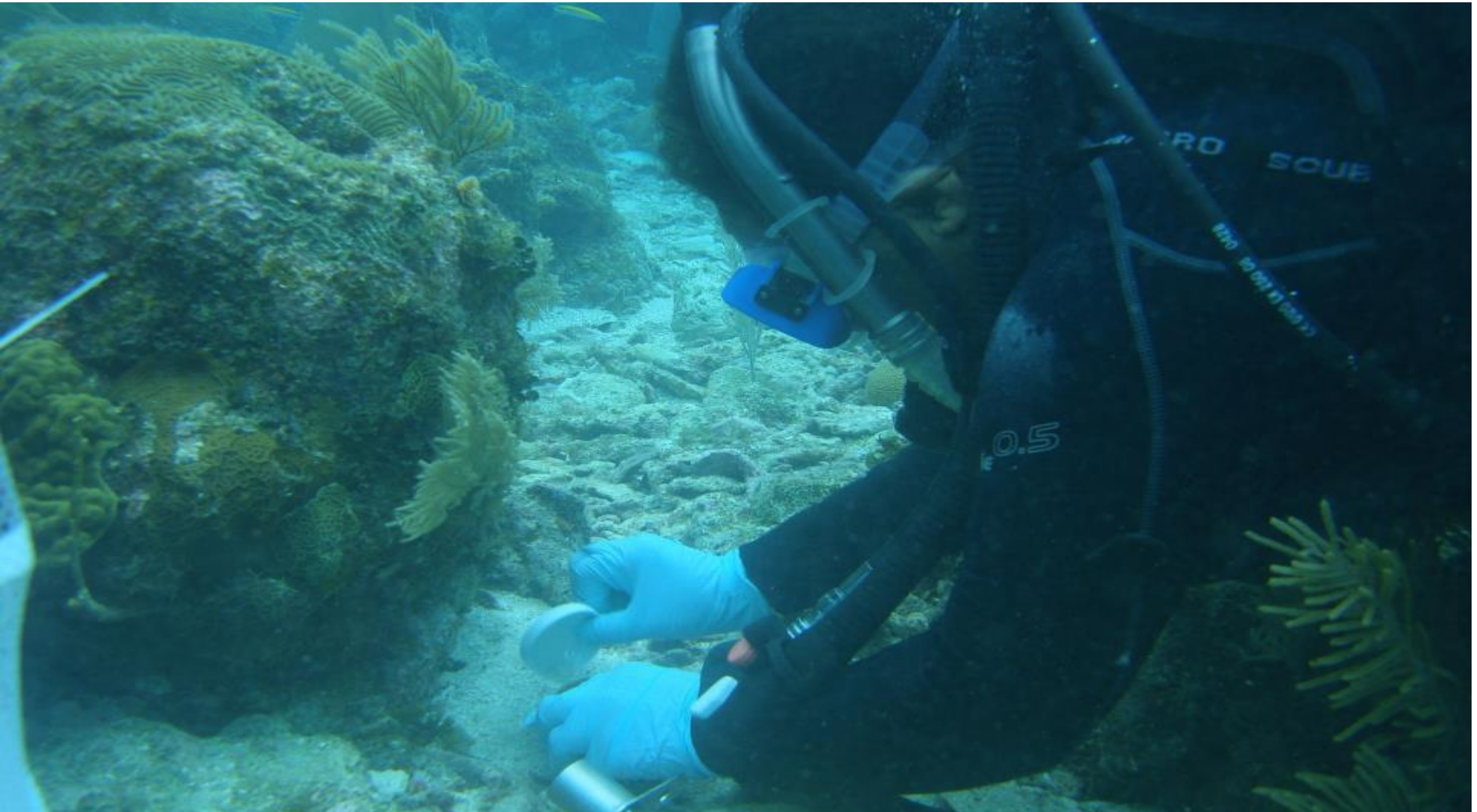
- ADPEN laboratories, accredited by both the U.S. Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA).

- 38 agrichemicals most widely used by the MAR's commercial agriculture industry.

Results 2013

PESTICIDE	CAYOS COCHINOS	BARBARETA	TURNEFFE	SAPODILLA	MONKEY RIVER	ULUA
CONCH TISSUE						
2,4-DCPA	0.10					
ACETAMIPRID	0.02					
DELTAMETHRIN	0.02			0.08		
EPOXICANAZOLE	0.01					
o,p DDT	0.00		0.00	0.01		
TRIDEMORPH	0.63	0.70	0.24	0.50		
CORAL TISSUE						
TRIDEMORPH	0.04		0.05	0.04		
FISH TISSUE						
TRIDEMORPH		0.50				
SEDIMENTS						
TRIDEMORPH	0.01				0.02	

4. Bioaccumulation 2019



Bioaccumulation 2019

- Fourth round of bio-accumulation
- Adpen labs
- 72 sediment samples (from reef and river);
- 32 fish samples (tissue, liver, and gonad);
- 16 coral samples;
- 12 conch tissue samples.

- The samples were taken from the same vicinity as those taken for the 2007, and 2013
- 30 agrichemicals most widely used by the MAR's commercial agriculture industry.

Results 2019 (Sediments only)

Active Ingredient	ULUA	CHAMELECON	BARBARETA	CAYOS COCHINOS
	Concentration (ppm) (MRL* 0.01)			
Malathion	0.08			0.02
Hexythiazox	0.08		0.02	
Thiacloprid	0.06	0.10		
Pyrethrin I	0.03			
Chlorantraniliprole	0.02			
Deltamethrin	0.01	0.09	0.02	0.01
Spinetoram J	0.01			
p,p-DT	0.01		0.01	0.01
Fenpyroximate	0.01			
Ethoprophos	0.01	0.01	0.01	

5. Bioaccumulation 2022

Bioaccumulation 2022

Fifth round of bio-accumulation sampling

Adpen labs

78 agrichemicals used by the MAR's commercial agriculture industry.

Results 2022

Pesticide	MRL (ppm)		SAMPLING SITES											
			SAPODILLA					TURNEFFE					N RIVER	M RIVER
			Sediment	Conch	Coral	F. Muscle	F. Liver	Sediment	Conch	Coral	F. Muscle	F. Liver	Sediment	Sediment
Azoxystrobin	0.05	EFS	0.01	0.19							0.14			
Bifenthrin	0.2	EFS		0.09										
Daminozide	0.02	EFS		0.62		0.05	0.22		0.19		0.11	0.18		
Fludioxonil	0.05	EFS	0.02											
Metalaxyl	0.02	EFS		0.22	0.01	0.05	0.01		0.01	0.01	0.01	0.01	0.01	
Oxamyl	0.01	EFS						0.02						
Prallethrin	1	EPA					1.68					1.02		
Pyrethrin I	1	EPA					0.11							
Pyrethrins	1	EPA					0.07							

Results 2022

Pesticide	Pesticide Type	PCB REGISTER 2021
Azoxystrobin	Fungicide (organic)/banana, other	Amistar, Bankit, Glory, Mirador, Uniform, Xstrata
Bifenthrin	Insecticide/ant control	Benaflex (banana tree bags) , Kilate, Seizer
Daminozide	Plant growth regulator	not in PCB data base
Fludioxonil	Fungicide/cereal, fruits,	Switch, Cruiser
Metalaxyl	Fungicide/citrus	Cruiser, Diligent, Uniform, Ridomil, Victory
Oxamyl	Nematicide (banana)	Vydate, Vydox,
Prallethrin	Repellent for mosquitoes	Suretox, Baygon, Raid, Protox citronella
Pyrethrin I	Insecticide	Pybuthrin (public health)
Pyrethrins		

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WWF, 28 rue Mauverney, 1196 Gland, Switzerland. Tel. +41 22 364 9111

CH-550.0.128.920-7

SUSPENDED SOLIDS, NITRATES, AND PHOSPHATES MONITORING

Agricultural runoff loaded with nitrates and phosphates cause eutrophication:

a) algae multiply. (some toxics)

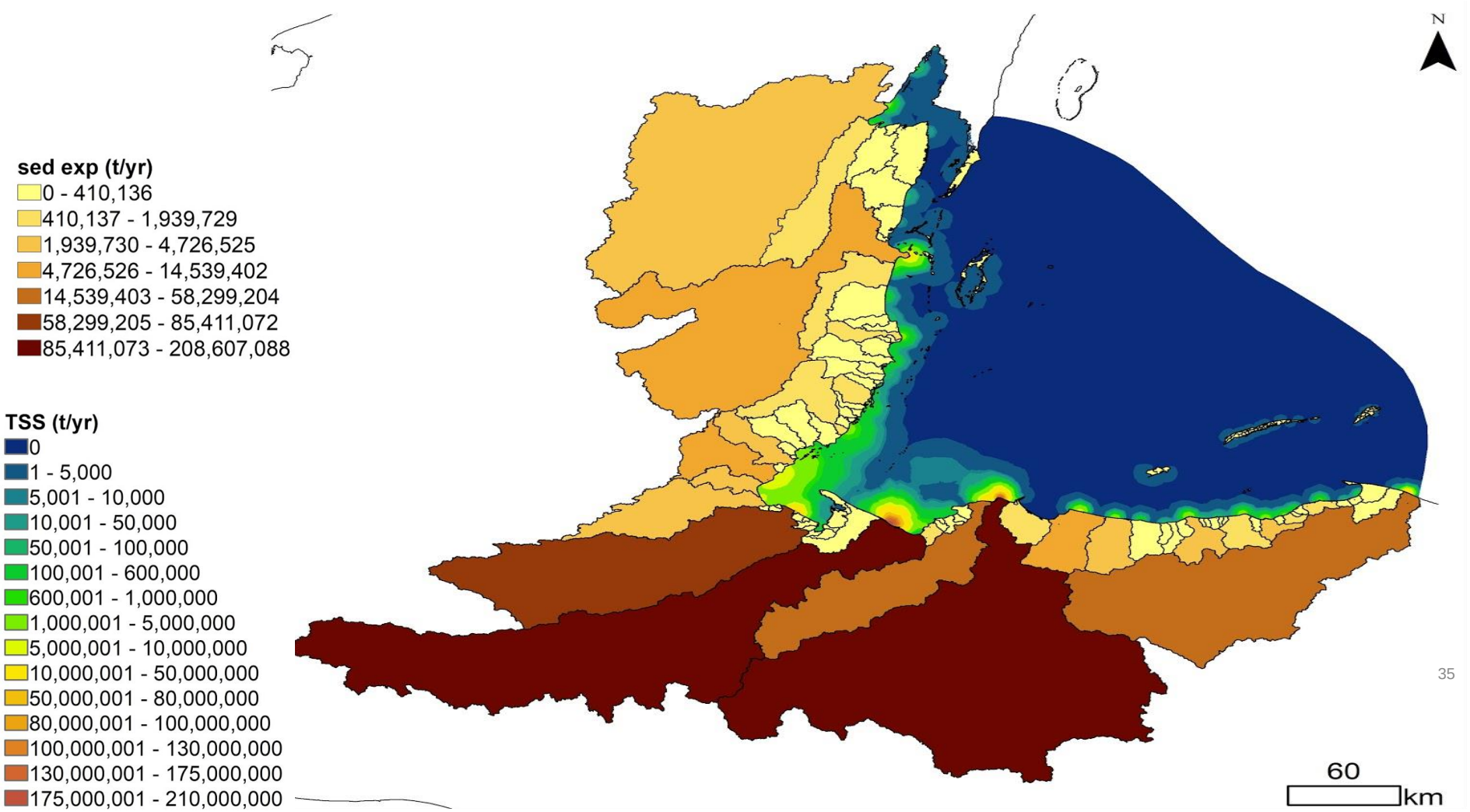
b) penetration of light into the water is reduced.

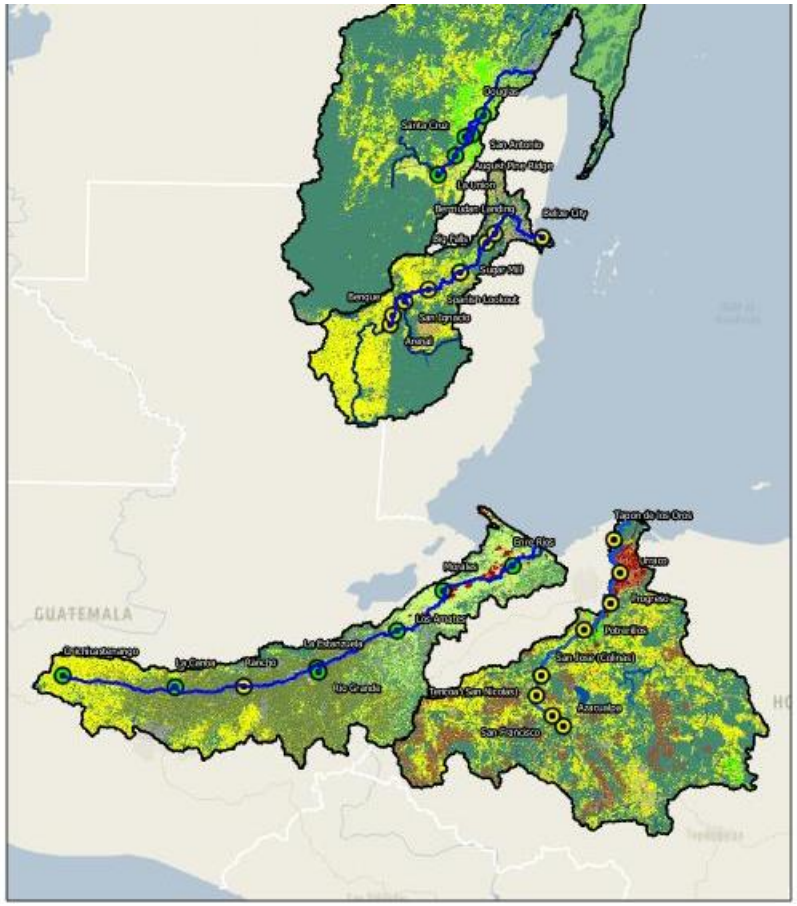
c) the oxygen in the water is depleted.

d) without oxygen results in the death of fish.

Suspended solids also reduce light penetration, reducing the algae's ability to produce food and oxygen

Baseline results: (IKI 2020)

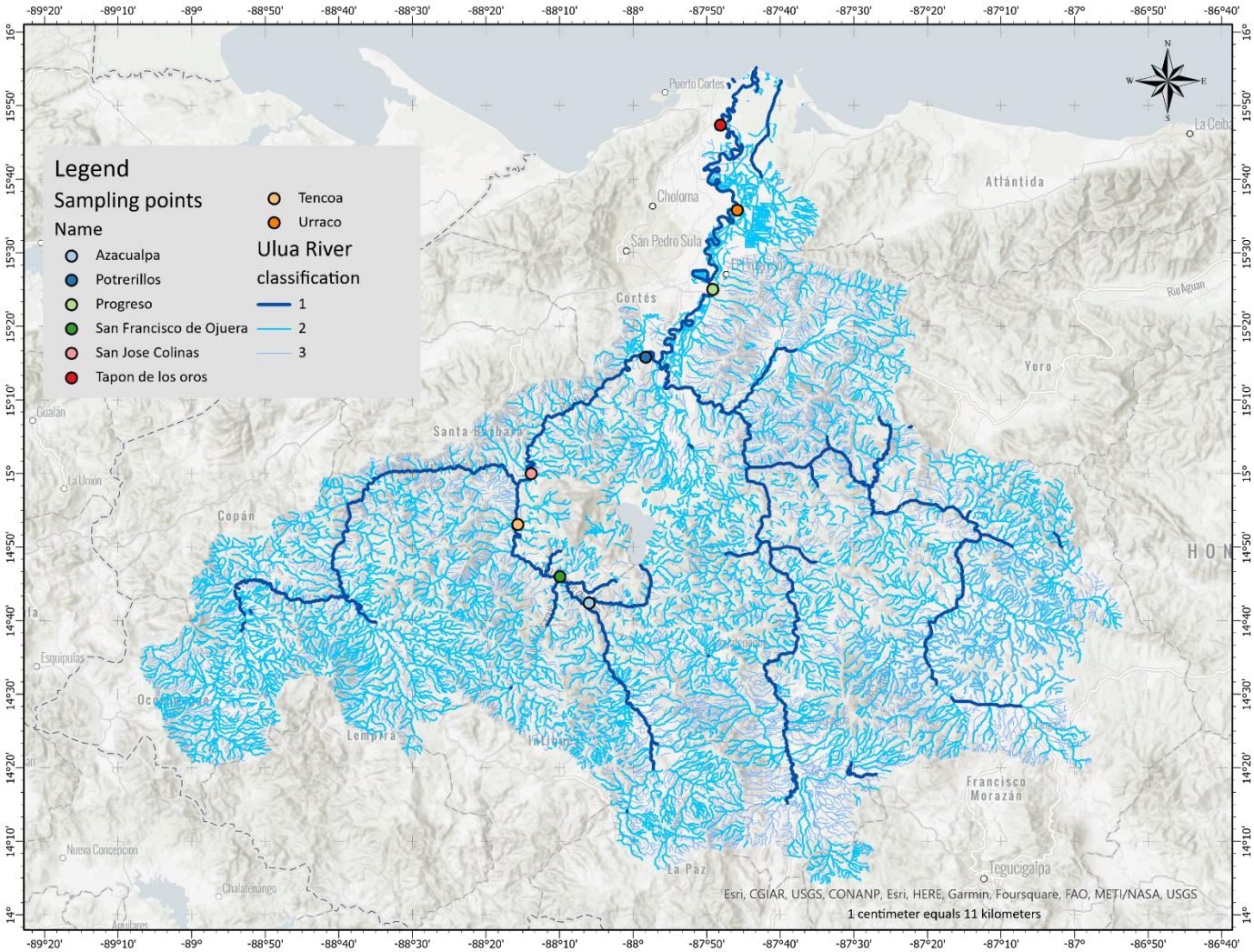


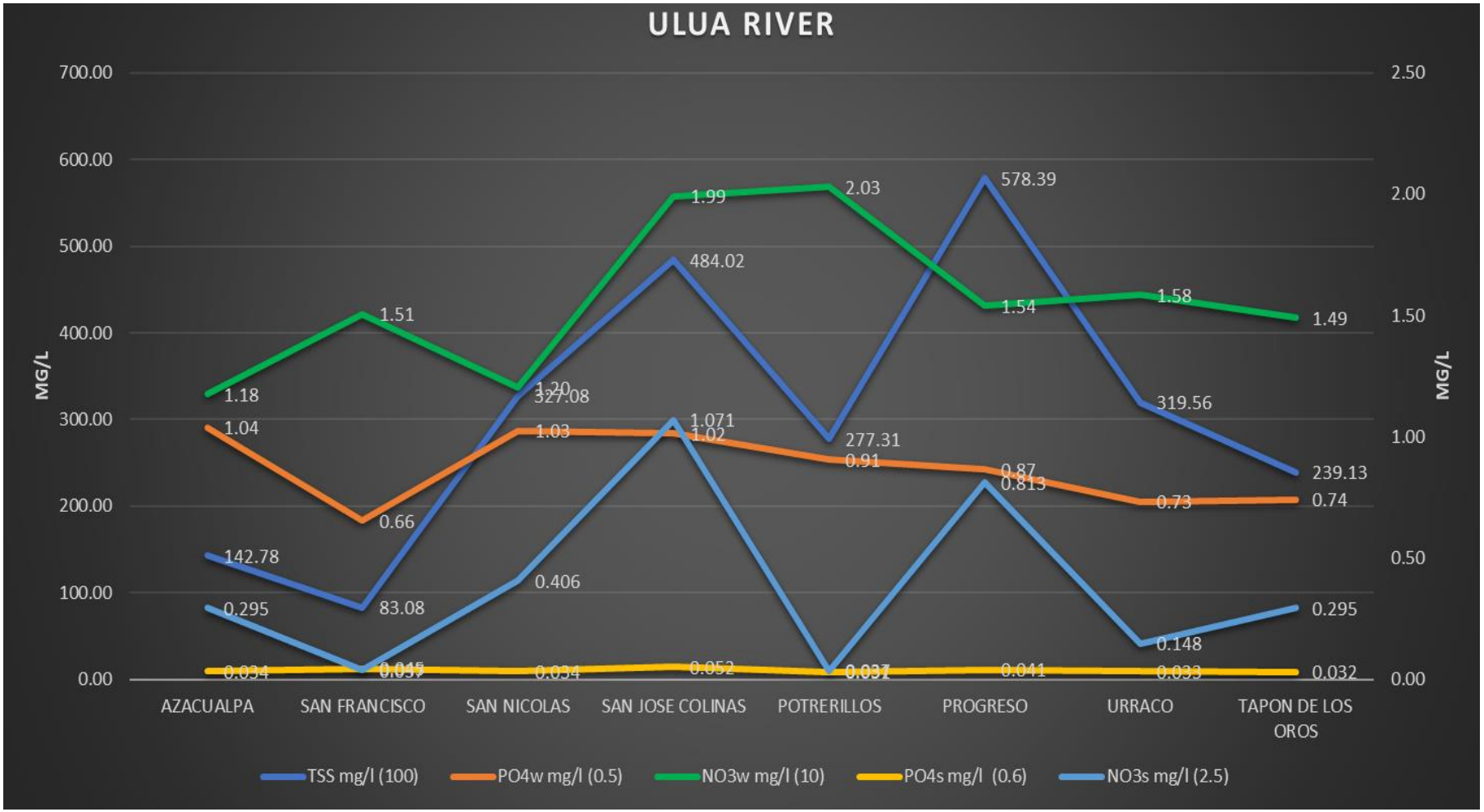


Whatersheds

- Ulua River
- Motagua River
- Belize River
- Río Hondo

ULUA


Legend
Sampling points
Name
Azacualpa
Potrerillos
Progreso
San Francisco de Ojuera
San Jose Colinas
Tapon de los oros
Tencoa
Urraco
Ulua River
classification
1
2
3
Puerto Cortes
La Ceiba
Choloma
San Pedro Sula
Atlántida
Cortés
Río Aguan
Yoro
Gualán
Santa Bárbara
La Unión
Copán
Esquipulas
Ocotepeque
Lempira
Francisco Morazán
Nueva Concepcion
Chalatenango
La Paz
Tegucigalpa
Esri, CGIAR, USGS, CONANP, Esri, HERE, Garmin, Foursquare, FAO, METI/NASA, USGS
1 centimeter equals 11 kilometers


ULUA RIVER
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
MG/L
2.50
2.00
1.50
1.00
0.50
0.00
MG/L
1.18
1.51
1.20
1.99
2.03
1.54
1.58
1.49
1.04
0.66
1.03
1.02
0.91
0.87
0.73
0.74
142.78
83.08
327.08
484.02
277.31
578.39
319.56
239.13
0.295
0.406
1.071
0.813
0.148
0.295
0.034
0.045
0.034
0.052
0.037
0.041
0.033
0.032
AZACUALPA
SAN FRANCISCO
SAN NICOLAS
SAN JOSE COLINAS
POTRERILLOS
PROGRESO
URRACO
TAPON DE LOS OROS
TSS mg/l (100)
PO4w mg/l (0.5)
NO3w mg/l (10)
PO4s mg/l (0.6)
NO3s mg/l (2.5)

Nitrates in Surface river water

Nitrates mg/l (surface water) ŷ=1.5																	
Sampling Site		Aug		Sep		Oct		Ene		Abr		May		ŷ	S.D	Limit	Norm
		2020	2021	2020	2021	2020	2021	2021	2022	2021	2022	2021	2022				
ULUA RIVER	AZACUALPA	2.490	0.290	1.680	2.370	3.030	1.930	0.021	0.290	0.290	0.410	1.030	0.290	1.177	1.07	10	Peru
	SAN FRANCISCO	2.150	1.980	1.350	2.880	1.560	3.560	0.091	2.540	0.290	0.420	0.960	0.290	1.506	1.14		
	SAN NICOLAS	1.680	0.740	1.530	2.280	1.870	2.470	0.040	2.170	0.290	0.440	0.640	0.290	1.203	0.88		
	SAN JOSE COLINAS	2.150	4.650	2.520	3.460	1.890	2.830	0.040	1.610	0.290	0.360	3.820	0.290	1.993	1.54		
	POTRERILLOS	1.960	4.000	2.340	4.730	1.850	3.160	0.021	1.800	0.290	0.990	2.930	0.290	2.030	1.50		
	PROGRESO	1.590	3.680	0.850	2.150	1.370	2.600	1.110	2.480	0.700	1.370	0.290	0.290	1.540	1.02		
	URRACO	2.290	0.290	1.770	3.980	1.900	2.510	1.060	2.450	0.620	1.560	0.290	0.290	1.584	1.14		
	TAPON DE LOS OROS	1.300	0.950	1.900	3.920	2.630	2.910	0.040	0.290	0.290	1.390	1.510	0.760	1.491	1.18		
Average and standard deviation														1.565	1.19		

Phosphates in Surface river water

Phosphates mg/l (water) ŷ=0.87																
Sampling Site		Aug		Sep		Oct		Ene		Abr		May		ŷ	S.D	Limit	Norm
		2020	2021	2020	2021	2020	2021	2021	2022	2021	2022	2021	2022				
ULUA RIVER	AZACUALPA	0.650	1.160	0.650	4.060	0.650	1.870	0.100	0.730	0.650	0.650	0.650	0.650	1.039	1.04	0.5	Peru
	SAN FRANCISCO	0.650	0.020	0.650	1.880	0.650	0.100	0.100	1.210	0.650	0.650	0.650	0.650	0.655	0.51		
	SAN NICOLAS	0.650	2.710	0.650	3.640	0.650	0.970	0.100	0.340	0.650	0.650	0.650	0.650	1.026	1.04		
	SAN JOSE COLINAS	0.650	2.710	0.650	3.020	0.650	0.790	0.100	1.010	0.650	0.650	0.650	0.650	1.015	0.89		
	POTRERILLOS	0.650	1.360	0.650	2.610	0.650	1.310	0.100	0.930	0.650	0.650	0.650	0.650	0.905	0.63		
	PROGRESO	0.650	0.540	0.650	4.370	0.650	0.680	0.100	0.690	0.650	0.650	0.650	0.100	0.865	1.12		
	URRACO	0.650	0.430	0.650	2.300	0.650	1.100	0.100	0.860	0.650	0.650	0.650	0.100	0.733	0.57		
	TAPON DE LOS OROS	0.650	0.430	0.650	2.090	0.650	0.960	0.100	0.890	0.650	0.650	1.170	0.010	0.742	0.54		
Average and standard deviation														0.872	0.81		

Total Suspended Solids in surface river water

Suspended Solids mg/l (water) ŷ=306.4																
Sampling Site		Aug		Sep		Oct		Ene		Abr		May		ŷ	S.D	Limit	Norm
		2020	2021	2020	2021	2020	2021	2021	2022	2021	2022	2021	2022				
ULUA RIVER	AZACUALPA	103.000	60.000	127.780	970.000	50.000	238.570	7.000	16.000	12.000	9.000	70.000	50.000	142.779	268.69	100	Peru
	SAN FRANCISCO	93.000	14.000	162.220	288.570	72.000	51.000	10.000	181.110	12.000	11.000	72.000	30.000	83.075	86.68		
	SAN NICOLAS	244.000	170.000	94.000	2,750.000	57.000	506.000	15.000	30.000	6.000	20.000	16.000	17.000	327.083	776.79		
	SAN JOSE COLINAS	850.000	510.000	563.330	1,360.000	69.000	162.000	19.000	161.110	4.830	25.000	1,800.000	284.000	484.023	581.29		
	POTRERILLOS	225.000	108.750	750.000	1,200.000	64.000	460.000	40.000	172.000	13.000	12.000	264.000	19.000	277.313	364.24		
	PROGRESO	135.000	34.000	412.500	4,610.000	111.000	257.500	31.000	156.670	35.000	48.000	1,070.000	40.000	578.389	1,303.19		
	URRACO	890.000	44.000	653.330	733.330	125.000	496.670	47.000	320.000	29.000	39.000	413.330	44.000	319.555	312.66		
	TAPON DE LOS OROS	140.000	90.000	357.500	420.000	280.000	940.000	90.000	242.000	37.000	69.000	122.000	82.000	239.125	252.65		
Average and standard deviation														306.418	610.50		

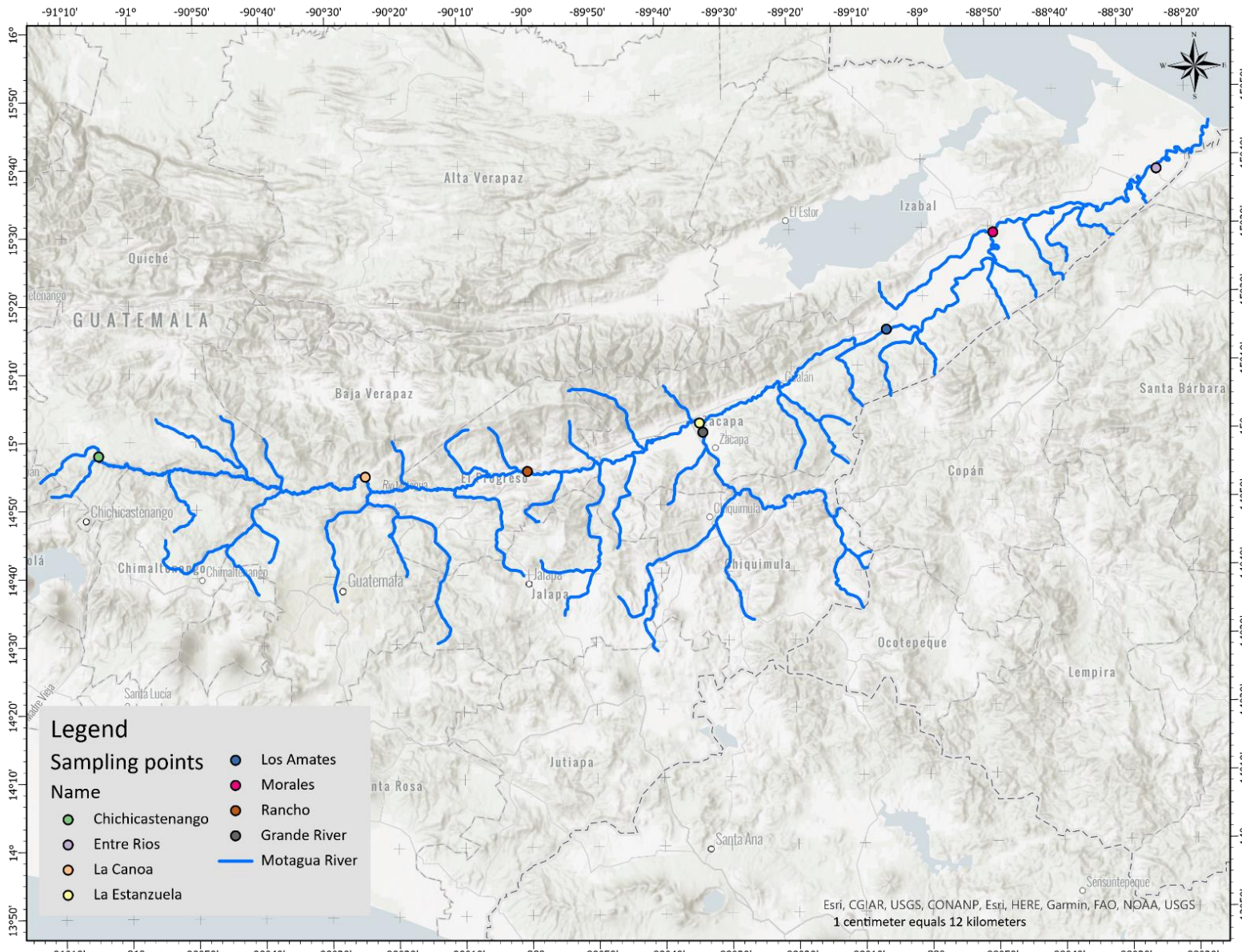
Nitrates in river sediments

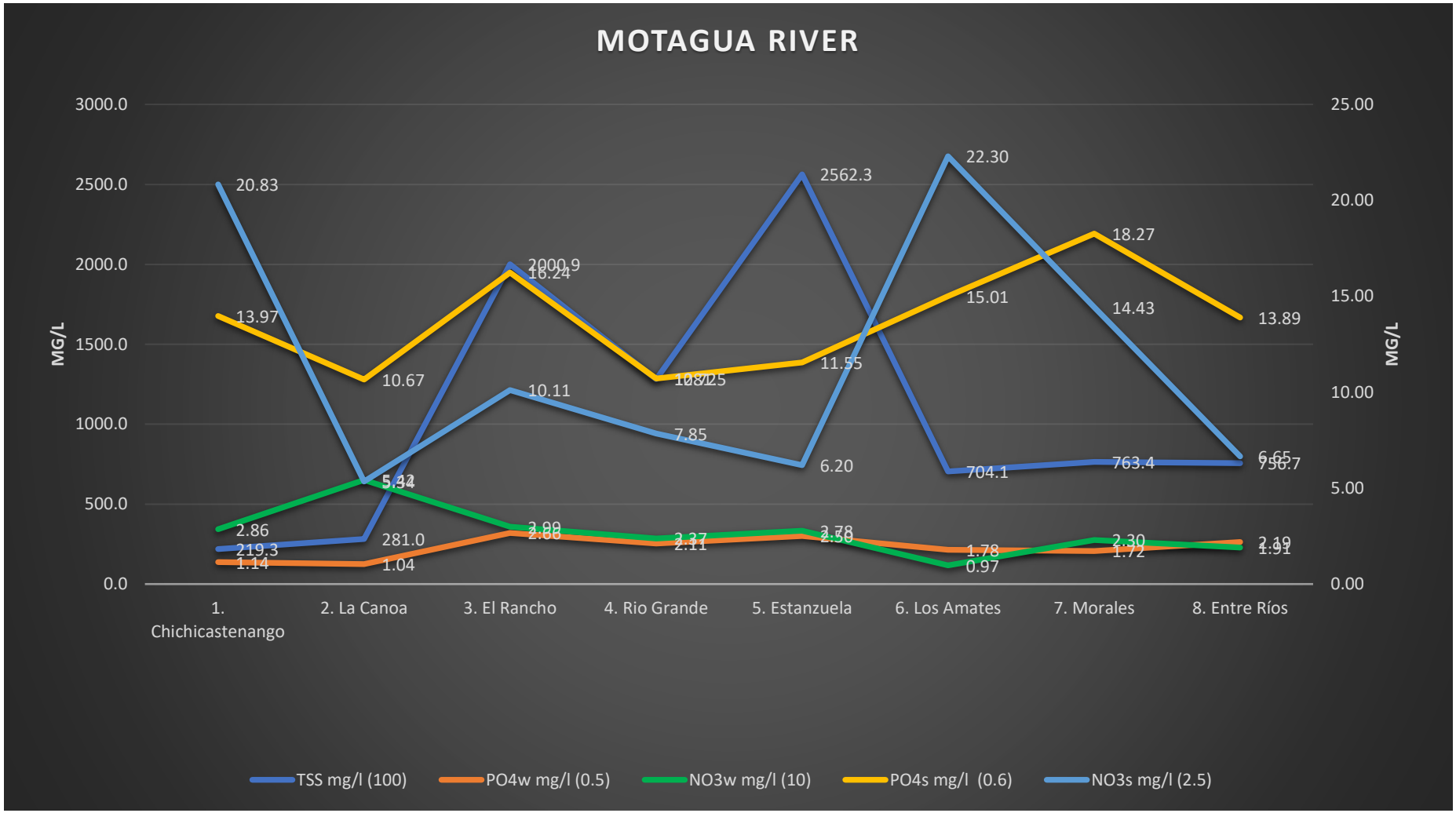
Nitrate mg/kg (sediment) ŷ=0.3																
Sampling Site		Aug		Sep		Oct		Ene		Abr		May		ŷ	S.D	Limit	Norm
		2020	2021	2020	2021	2020	2021	2021	2022	2021	2022	2021	2022				
ULUA RIVER	AZACUALPA	-	0.002	-	3.540	-	0.000	-	0.000	-	0.000	-	-	0.295	1.02	2.5	STMSEUE Cap 4.38
	SAN FRANCISCO	0.007	0.000	-	0.440	-	0.000	-	0.000	-	0.000	-	-	0.037	0.13		
	SAN NICOLAS	-	0.001	-	4.870	-	0.000	-	0.000	-	0.000	-	-	0.406	1.41		
	SAN JOSE COLINAS	-	0.001	-	12.850	-	0.000	-	0.000	-	0.000	-	-	1.071	3.71		
	POTRERILLOS	-	0.001	-	0.440	-	0.001	-	0.000	-	0.000	-	-	0.037	0.13		
	PROGRESO	-	0.001	-	9.750	-	0.000	-	0.000	-	0.000	-	-	0.813	2.81		
	URRACO	-	0.001	-	1.770	-	0.000	-	0.000	-	0.000	-	-	0.148	0.51		
	TAPON DE LOS OROS	-	0.001	0.002	3.540	-	0.000	-	0.000	-	0.000	-	-	0.295	1.02		
Average and standard deviation														0.388	1.77		

Phosphates in river sediments

Phosphate mg/kg (sediment) ŷ=0.03																	
Sampling Site		Aug		Sep		Oct		Ene		Abr		May		ŷ	S.D	Limit	Norm
		2020	2021	2020	2021	2020	2021	2021	2022	2021	2022	2021	2022				
ULUA RIVER	AZACUALPA	0.000	0.197	0.000	0.104	0.000	0.004	0.100	0.007	0.000	0.000	0.000	0.000	0.034	0.06	0.6	WSAM S-4.10:2007
	SAN FRANCISCO	0.000	0.255	0.000	0.081	0.000	0.100	0.100	0.003	0.000	0.000	0.000	0.000	0.045	0.08		
	SAN NICOLAS	0.000	0.201	0.000	0.058	0.000	0.026	0.100	0.027	0.000	0.000	0.000	0.000	0.034	0.06		
	SAN JOSE COLINAS	0.000	0.193	0.000	0.168	0.000	0.100	0.100	0.064	0.000	0.000	0.000	0.000	0.052	0.07		
	POTRERILLOS	0.000	0.162	0.000	0.065	0.000	0.049	0.100	0.001	0.000	0.000	0.000	0.000	0.031	0.05		
	PROGRESO	0.000	0.199	0.000	0.078	0.000	0.100	0.100	0.014	0.000	0.000	0.000	0.000	0.041	0.06		
	URRACO	0.000	0.157	0.000	0.089	0.000	0.048	0.100	0.000	0.000	0.000	0.000	0.000	0.033	0.05		
	TAPON DE LOS OROS	0.000	0.052	0.000	0.129	0.000	0.053	0.100	0.049	0.000	0.000	0.000	0.000	0.032	0.04		
Average and standard deviation														0.038	0.06		

MOTAGUA


Legend
Sampling points
Name
Chichicastenango
Entre Rios
La Canoa
La Estanzuela
Los Amates
Morales
Rancho
Grande River
Motagua River
Alta Verapaz
Quiché
GUATEMALA
Baja Verapaz
Izabal
El Estor
Santa Bárbara
Copán
Ocotepeque
Lempira
Chiquimula
Zacapa
Guatemala
Jalapa
Jutiapa
Santa Ana
Sensuntepeque
Chichicastenango
Esri, CGIAR, USGS, CONANP, Esri, HERE, Garmin, FAO, NOAA, USGS
1 centimeter equals 12 kilometers


MOTAGUA RIVER
MG/L
MG/L
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
25.00
20.00
15.00
10.00
5.00
0.00
20.83
2562.3
22.30
2000.9
16.24
18.27
13.97
15.01
14.43
13.89
10.67
11.55
10.11
7.85
6.20
704.1
763.4
756.7
2.86
281.0
219.3
1.14
1.04
1.78
1.72
0.97
1. Chichicastenango
2. La Canoa
3. El Rancho
4. Rio Grande
5. Estanzuela
6. Los Amates
7. Morales
8. Entre Ríos
TSS mg/l (100)
PO4w mg/l (0.5)
NO3w mg/l (10)
PO4s mg/l (0.6)
NO3s mg/l (2.5)

Nitrates in Surface river water

Nitrates mg/l (surface water) ŷ=2.7																						
Sampling Site		Aug		Oct		Nov		Dic		Ene		Feb		Mar		Abr		May		ŷ	S.D	Limit	Norm
		2020	2021	2020	2021	2020	2021	2020	2021	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
MOTAGUA RIVER	**1. Chichicastenango**	0.4	0.40	0.4	0.40	8.2	0.40	0.4	0.40	-0.4	0.40	0.4	0.40	0.4	0.40	36	0.40	2.05	0.40	2.86	8.48		
	2. La Canoa	0.4	0.40	0.4	0.40	0.4	0.40	0.4	0.40	-0.4	0.40	21.4	0.40	28.2	0.40	21.9	0.40	21.3	0.40	5.42	9.88		
	3. El Rancho	9.9	0.40	0.4	0.40	0.4	0.40	0.4	1.60	-24	0.40	15.9	3.00	6.1	3.00	16.87	0.40	17.2	1.00	2.99	9.10		
	4. Rio Grande	9.9	0.40	0.4	0.40	0.4	0.40	0.4	0.40	-20.2	0.40	8.4	0.40	8.3	0.40	19.32	0.40	12.2	0.40	2.37	7.93		
	5. Estanzuela	9.9	0.40	9.4	0.40	0.4	0.40	0.4	0.40	-25.7	0.40	9.8	0.40	8.7	0.40	20.29	0.40	11.7	1.90	2.78	9.18	10	Peru
	6. Los Amates	0.4	0.40	0.4	0.40	0.4	0.40	0.4	0.40	-15.2	0.40	5.1	0.40	6.8	0.40	5.8	0.40	9.8	0.40	0.97	4.96		
	7. Morales	0.4	0.40	0.4	0.40	0.4	0.40	21.4	0.40	-16.2	0.40	6.8	0.40	7.2	0.40	5.4	0.40	12	0.40	2.30	7.27		
	8. Entre Ríos	0.4	0.40	8.7	0.40	0.4	0.40	0.4	0.40	-18.4	0.40	9.1	0.40	9.5	0.40	6.9	0.40	13.7	0.40	1.91	6.68		
Average and Standard deviation																				2.70	7.96		

Phosphates in Surface river water

Phosphate mg/kg (sediment) ŷ13.79																							
Sampling Site		Aug		Oct		Nov		Dic		Ene		Feb		Mar		Abr		May		ŷ	S.D	Limit	Norm
		2020	2021	2020	2021	2020	2021	2020	2021	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
MOTAGUA RIVER	**1. Chichicastenango**	3.9	12.10	22.2	17.90	9	8.40	10.1	7.20	39.8	5.50	35.5	10.40	11.1	7.50	9.5	7.80	12.4	21.20	13.97	9.95		
	2. La Canoa	10.4	19.20	14.9	19.90	9.5	11.40	10.4	7.80	18.6	8.50	10.4	5.50	11.4	3.30	7.2	9.50	8.2	5.90	10.67	4.71		
	3. El Rancho	26.7	17.30	16.6	10.40	10.8	14.00	21.8	6.80	18.6	17.00	7.2	22.20	12.7	15.60	9.5	31.00	23.8	10.40	16.24	6.82		
	4. Rio Grande	4.9	6.50	32.6	8.80	9.8	9.50	2.9	4.60	16	9.80	7.2	7.20	11.1	7.80	10.8	16.30	21.2	5.90	10.72	7.12		
	5. Estanzuela	12.4	8.20	3.6	8.20	11	6.80	4.2	8.20	16	16.60	8.2	4.20	11.7	17.30	11.7	22.50	18.8	18.30	11.55	5.62	0.6	WSAM S-4.10:2007
	6. Los Amates	6.2	23.80	24.8	16.30	6.8	18.30	2.9	10.10	18.3	13.70	9.5	13.00	12.7	13.60	11.4	12.70	19.6	36.50	15.01	7.88		
	7. Morales	25.1	15.00	23.1	16.30	4.9	30.40	5.5	6.50	16	104.60	10.4	5.20	12.1	2.60	9.5	9.50	22.1	10.10	18.27	22.91		
	8. Entre Ríos	42.4	23.10	11.1	16.30	1	12.10	3.6	4.90	17	6.80	8.5	9.80	10.8	18.50	12.7	18.30	26.7	6.50	13.89	9.83		
Average and Standard deviation																				13.79	10.84		

Total Suspended Solids in surface river water

Suspended Solids mg/l (water) ŷ=1,071.14																						
Sampling Site		Aug		Oct		Nov		Dic		Ene		Feb		Mar		Abr		May		ŷ	S.D	Limit	Norm
		2020	2021	2020	2021	2020	2021	2020	2021	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
MOTAGUA RIVER	**1. Chichicastenango**	94	106	74.0	246	207.5	276	100	0.26	54	11	11	143	134.00	1,600	463.30	2	370.00	56	219.32	368.28		
	2. La Canoa	95	206	287.1	614	2.0	19	41	1.25	9	10	24	9	1,986.70	26	463.10	50	1,150.00	64	280.95	519.28		
	3. El Rancho	1950	1,650	806.7	1,152	27,800.0	29	8	23	535	17	36	44	6.0	3	423.0	57	1,330.0	147	2,000.94	6,469.56		
	4. Rio Grande	1470	210	832.0	1,600	15,700.0	996	12	63	543	38	15	4	21.0	1	447.0	35	1,020.0	60	1,281.51	3,637.42		
	5. Estanzuela	1200	1,160	816.7	2,388	36,800.0	939	35	169	621	20	29	6	12.0	31	428.0	20	1,200.0	246	2,562.25	8,568.77	100	Peru
	6. Los Amates	685	933	4,580.0	1,453	490.0	1,605	6	329	209	440	17	26	23.0	15	465.3	130	1,090.0	176	704.05	1,087.96		
	7. Morales	1020	1,130	5,580.0	1,177	583.3	1,073	3	199	130	76	18	116	22.0	517	447.1	1	1,250.0	398	763.35	1,285.81		
	8. Entre Ríos	3240	1,555	3,760.0	324	490.0	623	23	350	138	234	20	97	27.0	323	433.3	160	1,200.0	623	756.71	1,080.12		
Average and Standard deviation																				1,071.14	4,050.56		

Nitrates in river sediments

Nitrate mg/kg (sediment) ŷ=11.71																						
Sampling Site		Aug		Oct		Nov		Dic		Ene		Feb		Mar		Abr		May		ŷ	S.D	Limit	Norm
		2020	2021	2020	2021	2020	2021	2020	2021	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
MOTAGUA RIVER	**1. Chichicastenango**	2.4	2.90	5.2	5.10	4.4	10.80	8.4	6.50	7	5.50	282.5	5.80	2.9	5.20	6.4	2.50	8.5	3.00	20.83	65.34	2.5	
	2. La Canoa	5.8	10.80	2.4	11.50	5	9.40	3.6	2.50	4.4	8.50	7.5	3.30	3.2	2.50	3.7	3.50	6	2.50	5.34	2.98		
	3. El Rancho	3	29.00	9	4.40	4.3	2.60	26	3.20	16.4	17.00	8.6	7.90	5	9.40	8.4	11.10	14.1	2.50	10.11	7.78		
	4. Rio Grande	2.4	21.30	26.8	2.50	5.3	6.30	4.3	2.50	10.8	9.80	9.2	2.50	6.5	5.10	7.3	4.80	11.4	2.50	7.85	6.65		STMSEU
	5. Estanzuela	2.4	8.00	2.6	2.50	4.4	2.50	2.7	2.50	12	16.60	7.1	3.90	8.3	7.70	9.6	3.60	8	7.20	6.20	3.94		E Cap
	6. Los Amates	2.4	287.50	11.8	3.00	2.7	5.50	2.5	2.50	7.7	13.70	7.6	2.50	6.5	5.30	10.9	5.80	13.4	10.10	22.30	66.30		4.38
	7. Morales	12.6	8.70	6.3	3.00	3.3	3.50	2.5	2.60	10.2	104.60	6.2	2.50	61	2.50	8.7	2.50	13.7	5.30	14.43	26.22		
	8. Entre Ríos	14.5	5.90	6.5	3.00	2.5	2.50	2.5	2.50	13.1	6.80	8.3	2.50	8.9	4.80	9.5	2.50	19	4.40	6.65	4.83		
Average and Standard deviation																				11.71	34.20		

Phosphates in river sediments

Phosphate mg/kg (sediment) ŷ13.79																						
Sampling Site		Aug		Oct		Nov		Dic		Ene		Feb		Mar		Abr		May		ŷ	S.D	Limit	Norm
		2020	2021	2020	2021	2020	2021	2020	2021	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
MOTAGUA RIVER	**1. Chichicastenango**	3.9	12.10	22.2	17.90	9	8.40	10.1	7.20	39.8	5.50	35.5	10.40	11.1	7.50	9.5	7.80	12.4	21.20	13.97	9.95		
	2. La Canoa	10.4	19.20	14.9	19.90	9.5	11.40	10.4	7.80	18.6	8.50	10.4	5.50	11.4	3.30	7.2	9.50	8.2	5.90	10.67	4.71		
	3. El Rancho	26.7	17.30	16.6	10.40	10.8	14.00	21.8	6.80	18.6	17.00	7.2	22.20	12.7	15.60	9.5	31.00	23.8	10.40	16.24	6.82		
	4. Rio Grande	4.9	6.50	32.6	8.80	9.8	9.50	2.9	4.60	16	9.80	7.2	7.20	11.1	7.80	10.8	16.30	21.2	5.90	10.72	7.12		
	5. Estanzuela	12.4	8.20	3.6	8.20	11	6.80	4.2	8.20	16	16.60	8.2	4.20	11.7	17.30	11.7	22.50	18.8	18.30	11.55	5.62	0.6	WSAM S-4.10:2007
	6. Los Amates	6.2	23.80	24.8	16.30	6.8	18.30	2.9	10.10	18.3	13.70	9.5	13.00	12.7	13.60	11.4	12.70	19.6	36.50	15.01	7.88		
	7. Morales	25.1	15.00	23.1	16.30	4.9	30.40	5.5	6.50	16	104.60	10.4	5.20	12.1	2.60	9.5	9.50	22.1	10.10	18.27	22.91		
	8. Entre Ríos	42.4	23.10	11.1	16.30	1	12.10	3.6	4.90	17	6.80	8.5	9.80	10.8	18.50	12.7	18.30	26.7	6.50	13.89	9.83		
Average and Standard deviation																				13.79	10.84		

Belize River

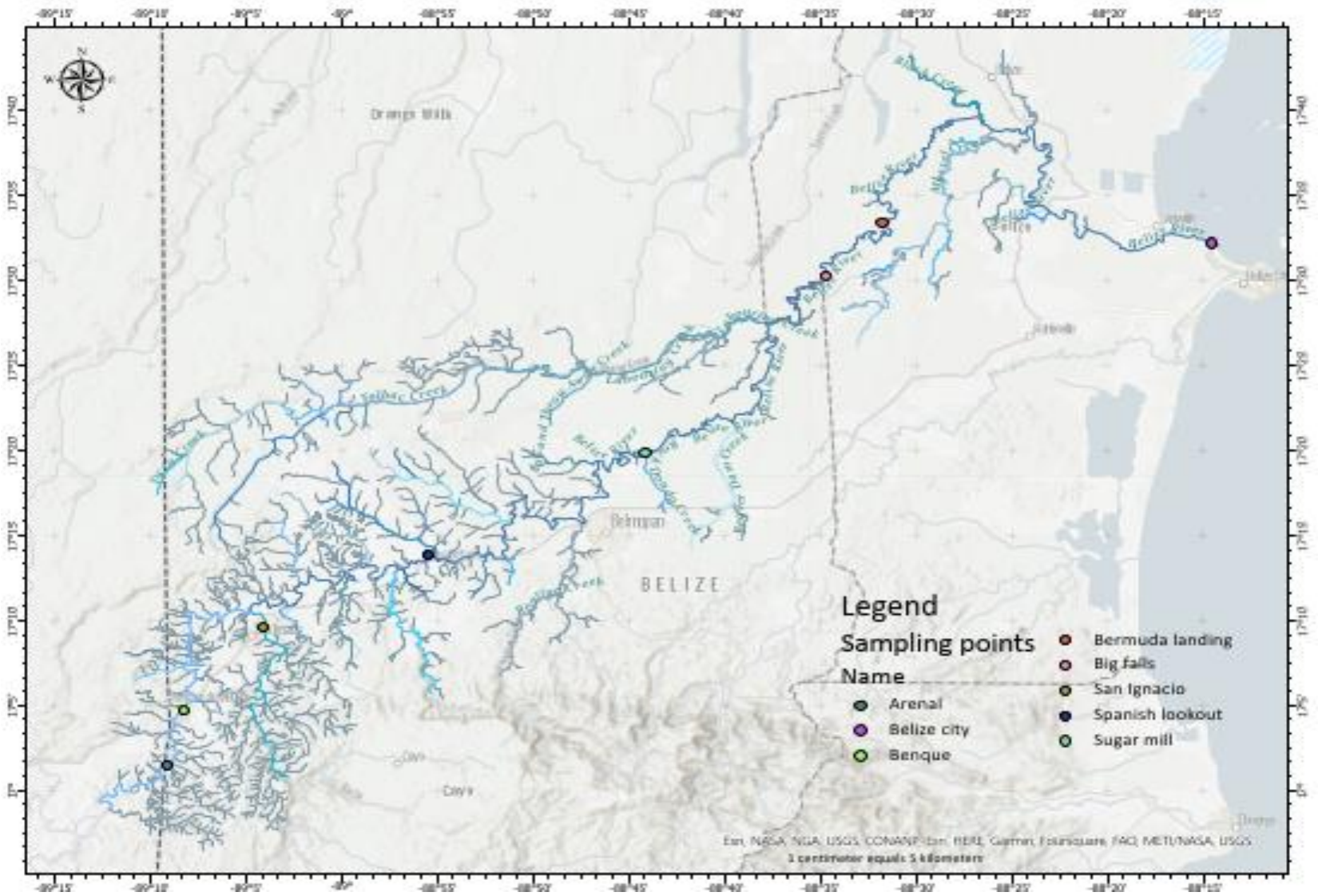
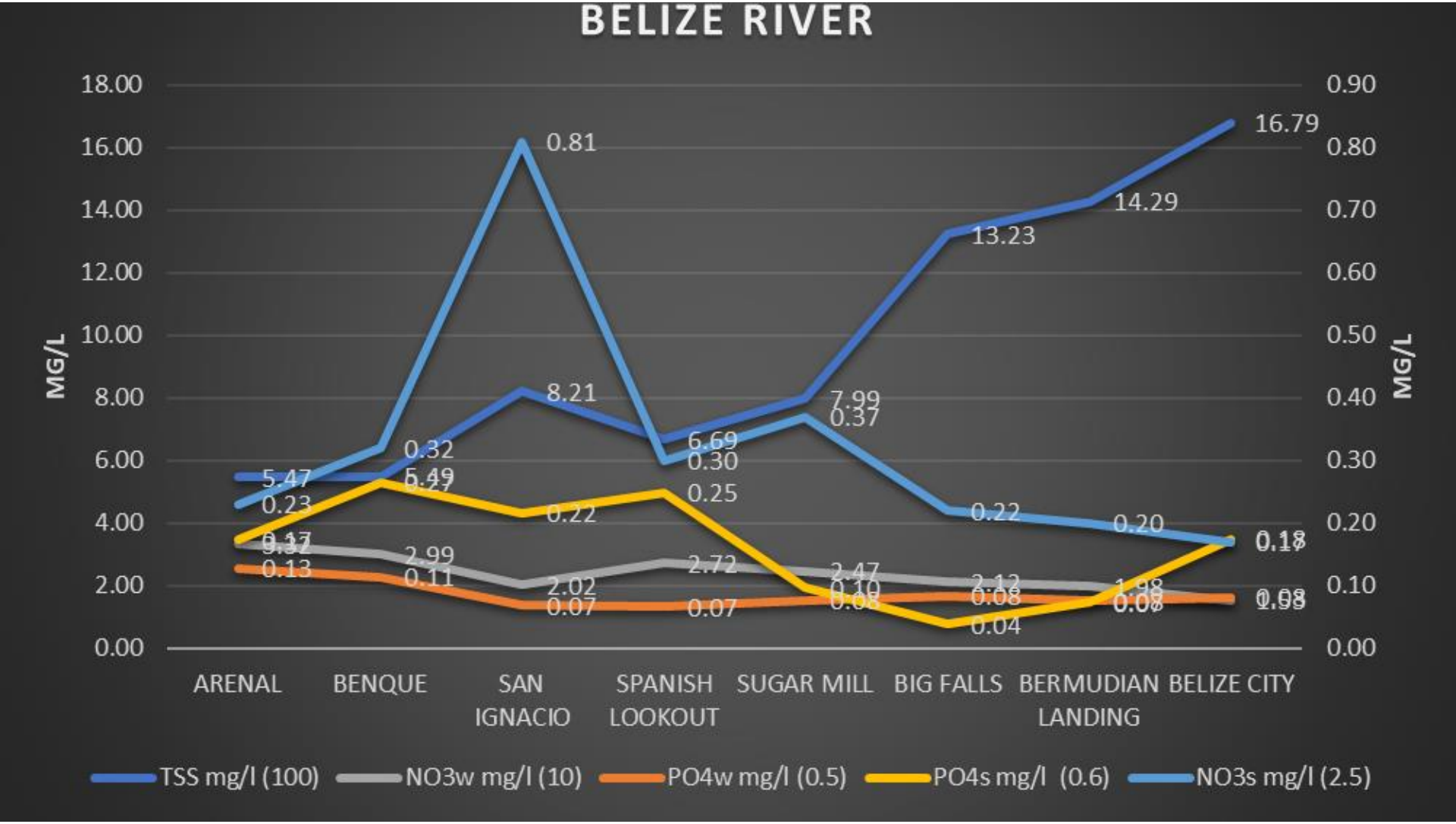


Figure 1. Belize River drainage basin. Sampling points for nitrates, phosphates, and total suspended solids


BELIZE RIVER
MG/L
MG/L
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
ARENAL
BENQUE
SAN IGNACIO
SPANISH LOOKOUT
SUGAR MILL
BIG FALLS
BERMUDIAN LANDING
BELIZE CITY
TSS mg/l (100)
NO3w mg/l (10)
PO4w mg/l (0.5)
PO4s mg/l (0.6)
NO3s mg/l (2.5)

Nitrates in Surface river water

Nitrates mg/l (surface water) ŷ=2.39															
Sampling Site		Feb		Mar		Apr		May		Jun		ŷ	S.D	**Limit**	**Norm**
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
BELIZE RIVER	ARENAL	2.8	4.00	3.20	4.5	3.20	3.3	4.60	2.6	2.20	2.8	3.32	0.81	10	Peru
	BENQUE	2.8	4.00	3.10	4.6	3.10	3.2	2.30	2.9	1.90	2	2.99	0.84		
	SAN IGNACIO	2.4	1.90	2.00	3.2	1.90	2.1	1.40	2	1.80	1.5	2.02	0.50		
	SPANISH LOOKOUT	2.4	2.10	3.00	3.3	1.30	3.7	3.00	4.4	2.00	2	2.72	0.93		
	SUGAR MILL	2.3	2.90	2.60	4.2	2.70	2.8	2.20	1.3	2.00	1.7	2.47	0.79		
	BIG FALLS	2	2.30	2.50	3	2.20	2.5	1.50	1.4	2.10	1.7	2.12	0.49		
	BERMUDIAN LANDING	1.8	2.90	2.20	3.2	2.20	1.8	1.50	0.6	1.90	1.7	1.98	0.72		
	BELIZE CITY	1.6	2.00	1.20	1.7	1.30	1.5	1.90	1.7	1.50	0.9	1.53	0.33		
Average and standard deviation												2.39	0.87		

Phosphates in Surface river water

Phosphates mg/l (water) ŷ=0.09														
Sampling Site		Feb		Mar		Apr		May		Jun		ŷ	S.D	**Limit**	**Norm**
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
BELIZE RIVER	ARENAL	0.03	0.04	0.06	0.06	0.03	0.02	0.76	0.08	0.14	0.06	0.13	0.22	0.5	Peru
	BENQUE	0.04	0.05	0.04	0.02	0.46	0.02	0.14	0.1	0.25	0.02	0.11	0.14		
	SAN IGNACIO	0.05	0.07	0.04	0.03	0.02	0.02	0.03	0.14	0.19	0.1	0.07	0.06		
	SPANISH LOOKOUT	0.05	0.02	0.02	0.07	0.03	0.11	0.09	0.09	0.12	0.07	0.07	0.04		
	SUGAR MILL	0.03	0.02	0.02	0.1	0.06	0.04	0.06	0.21	0.19	0.04	0.08	0.07		
	BIG FALLS	0.03	0.13	0.02	0.08	0.02	0.02	0.06	0.18	0.28	0.02	0.08	0.09		
	BERMUDIAN LANDING	0.02	0.03	0.04	0.09	0.03	0.04	0.13	0.16	0.21	0	0.08	0.07		
	BELIZE CITY	0.05	0.03	0.04	0.03	0.03	0.02	0.29	0.16	0.13	0.03	0.08	0.09		
Average and standard deviation												0.09	0.11		

Total Suspended Solids in surface river water

Suspended Solids mg/l (water) ŷ=9.77														
Sampling Site		Feb		Mar		Apr		May		Jun		ŷ	S.D	**Limit**	**Norm**
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
BELIZE RIVER	ARENAL	6.70	4.00	4.00	4.2	4.00	4.0	4.00	4.0	11.60	8.2	5.47	2.61	100	Peru
	BENQUE	5.00	4.00	4.00	4.7	4.20	4.0	4.00	4.0	13.60	7.4	5.49	3.04		
	SAN IGNACIO	4.00	4.00	4.00	33.2	4.00	4.0	4.00	13.0	5.30	6.6	8.21	9.22		
	SPANISH LOOKOUT	9.90	5.20	4.00	9.2	4.00	8.6	5.60	4.0	12.40	4.0	6.69	3.08		
	SUGAR MILL	10.30	5.50	4.00	10.9	4.00	4.0	5.60	4.9	16.50	14.2	7.99	4.65		
	BIG FALLS	37.50	12.20	4.00	11.6	8.00	4.8	4.00	4.0	21.20	25.0	13.23	11.30		
	BERMUDIAN LANDING	26.10	8.90	4.80	15.3	7.80	24.2	4.00	13.3	22.40	16.1	14.29	8.00		
	BELIZE CITY	4.80	10.60	13.40	4.0	4.00	14.2	92.40	5.7	14.20	4.6	16.79	26.92		
Average and standard deviation												9.77	11.68		

Nitrates in river sediments

Nitrate mg/kg (sediment) ŷ= 0.33															
Sampling Site		Feb		Mar		Apr		May		Jun		ŷ	S.D	**Limit**	**Norm**
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
BELIZE RIVER	ARENAL	0.3	0.90	0.10	0	1.00	0	0.00	0	0.00	0	0.23	0.39	2.5	STMSEUE Cap 4.38
	BENQUE	0.1	1.20	0.00	1.2	0.40	0	0.00	0.1	0.00	0.2	0.32	0.48		
	SAN IGNACIO	0.8	0.70	0.90	1.3	0.70	0	1.10	1.1	1.40	0.1	0.81	0.47		
	SPANISH LOOKOUT	0.1	0.50	0.00	0.4	0.00	0	0.00	1.3	0.00	0.7	0.30	0.43		
	SUGAR MILL	1.1	0.10	0.00	0.5	0.40	0.1	0.00	0	1.30	0.2	0.37	0.47		
	BIG FALLS	0.1	0.50	0.00	1.2	0.00	0	0.00	0.4	0.00	0	0.22	0.39		
	BERMUDIAN LANDING	0.1	0.30	0.00	0.1	0.30	0	0.00	1.2	0.00	0	0.20	0.37		
	BELIZE CITY	0.1	0.10	0.00	0.1	0.30	0	0.00	1	0.00	0.1	0.17	0.31		
Average and standard deviation												0.33	0.44		

Phosphates in river sediments

Phosphate mg/kg (sediment) ŷ=.16															
Sampling Site		Feb		Mar		Apr		May		Jun		ŷ	S.D	**Limit**	**Norm**
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
BELIZE RIVER	ARENAL	0.22	0.06	0.05	0.18	0.24	0	0.24	0.13	0.48	0.13	0.17	0.14	0.6	WSAM S-4.10:2007
	BENQUE	0	0.14	0.00	0.35	1.60	0	0.28	0	0.00	0.28	0.27	0.49		
	SAN IGNACIO	0.22	0.08	0.18	0.13	0.12	0.18	0.42	0.15	0.29	0.39	0.22	0.12		
	SPANISH LOOKOUT	0.45	0.07	0.20	0.11	0.26	0.26	0.22	0.2	0.43	0.29	0.25	0.12		
	SUGAR MILL	0.17	0.08	0.12	0.02	0.24	0.13	0.00	0.07	0.00	0.14	0.10	0.08		
	BIG FALLS	0	0.05	0.18	0	0.00	0	0.16	0	0.00	0	0.04	0.07		
	BERMUDIAN LANDING	0.1	0.07	0.00	0.1	0.18	0	0.00	0.05	0.00	0.23	0.07	0.08		
	BELIZE CITY	0.03	0.06	0.17	0.25	0.26	0.33	0.30	0.14	0.00	0.21	0.18	0.12		
Average and standard deviation												0.16	0.21		

Río Hondo

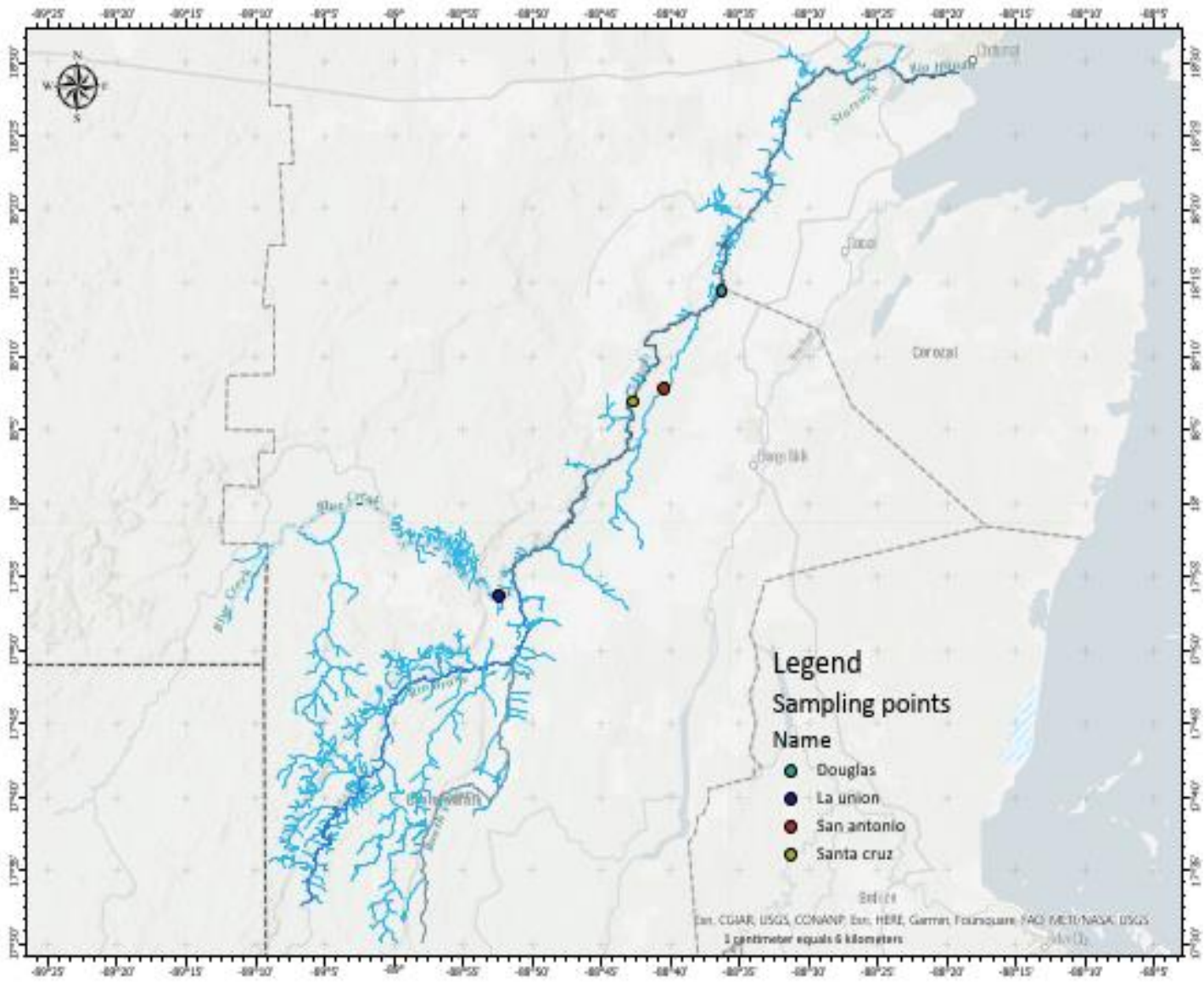
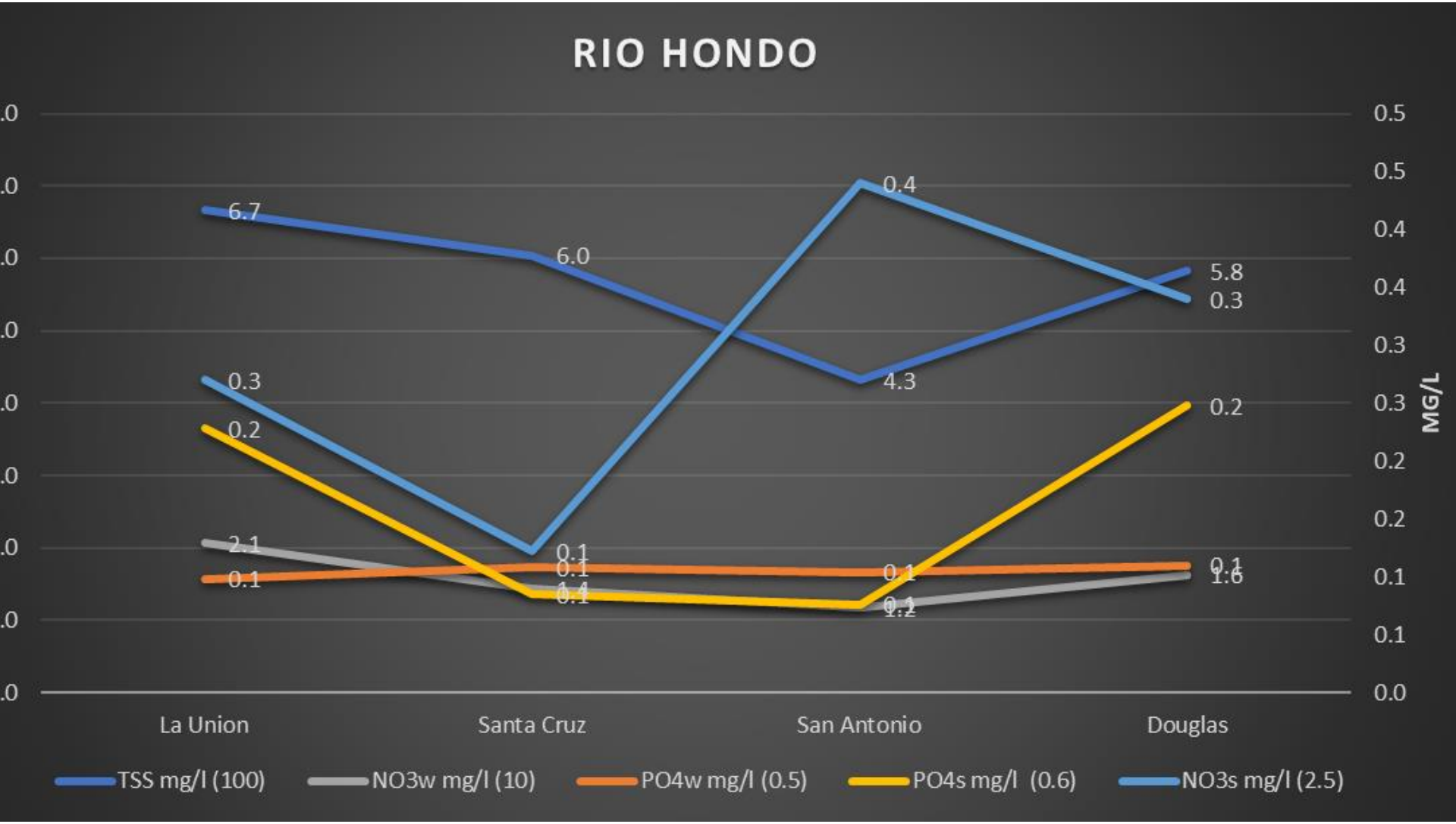


Figure 3. Hondo River drainage basin. Sampling points for nitrates, phosphates, and total suspended solids


RIO HONDO
0.5
0.5
0.4
0.4
0.3
0.3
0.2
0.2
0.1
0.1
0.0
MG/L
6.7
6.0
4.3
5.8
0.3
0.4
0.3
0.2
0.2
2.1
0.1
0.1
0.1
0.1
0.1
1.6
La Union
Santa Cruz
San Antonio
Douglas
TSS mg/l (100)
NO3w mg/l (10)
PO4w mg/l (0.5)
PO4s mg/l (0.6)
NO3s mg/l (2.5)

Nitrates in Surface river water

Nitrates mg/l (surface water) ŷ=1.57															
Sampling Site		Feb		Mar		Apr		May		Jun		ŷ	S.D	**Limit**	**Norm**
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
HONDO RIVER	La Union	3	2.60	2.80	2.7	2.70	2.3	1.50	1.5	1.5	0.02	2.06	0.93	10	Peru
	Santa Cruz	1.6	1.30	1.30	1.5	1.40	1.4	1.60	2.1	1.1	1	1.43	0.31		
	San Antonio	0.9	1.40	1.60	1.4	1.30	1.4	1.20	0.8	0.7	1	1.17	0.30		
	Douglas	1.8	1.40	1.70	2.2	2.10	2	1.50	1.5	1.1	1	1.63	0.41		
Average and standard deviation												1.57	0.62		

Phosphates in Surface river water

Phosphates mg/l (water) ŷ=0.11															
Sampling Site		Feb		Mar		Apr		May		Jun		ŷ	S.D	**Limit**	**Norm**
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
HONDO RIVER	La Union	0.02	0.03	0.07	0.05	0.13	0.05	0.26	0.12	0.21	0.04	0.10	0.08	0.5	Peru
	Santa Cruz	0.06	0.05	0.06	0.02	0.02	0.02	0.11	0.22	0.5	0.02	0.11	0.15		
	San Antonio	0.06	0.06	0.04	0.02	0.03	0.03	0.26	0.31	0.21	0.02	0.10	0.11		
	Douglas	0.05	0.03	0.06	0.03	0.04	0.03	0.16	0.36	0.32	0.02	0.11	0.13		
Average and standard deviation												0.11	0.12		

Total Suspended Solids in surface river water

Suspended Solids mg/l (water) ŷ=5.72															
Sampling Site		Feb		Mar		Apr		May		Jun		ŷ	S.D	**Limit**	**Norm**
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
HONDO RIVER	La Union	5.3	7.00	4.00	4.0	5.80	8.4	4.00	4.0	5.4	18.8	6.67	4.51	100	Peru
	Santa Cruz	6.8	7.80	4.00	4.0	8.00	5.0	7.40	7.4	6.0	4.0	6.04	1.66		
	San Antonio	4	4.00	4.00	6.8	4.40	4.0	4.00	4.0	4.0	4.0	4.32	0.88		
	Douglas	8	5.40	4.00	4.0	8.00	4.0	4.00	11.1	4.0	5.8	5.83	2.45		
Average and standard deviation												5.72	2.77		

Nitrates in river sediements

Nitrate mg/kg (sediment) ŷ=0.29															
Sampling Site		Feb		Mar		Apr		May		Jun		ŷ	S.D	**Limit**	**Norm**
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
HONDO RIVER	La Union	0.1	0.30	0.00	0.1	1.10	0	0.00	1	0	0.1	0.27	0.42	2.5	STMSEUE Cap 4.38
	Santa Cruz	0.1	0.90	0.00	0.22	0.00	0	0.00	0	0	0	0.12	0.28		
	San Antonio	1.4	1.50	0.00	0	0.00	0	0.00	0.7	0.7	0.1	0.44	0.60		
	Douglas	0.1	0.90	0.00	0.6	0.10	0	0.00	0.4	1.2	0.1	0.34	0.43		
Average and standard deviation												0.29	0.45		

Phosphates in river sediments

Phosphate mg/kg (sediment) ŷ=0.16															
Sampling Site		Feb		Mar		Apr		May		Jun		ŷ	S.D	**Limit**	**Norm**
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022				
HONDO RIVER	La Union	0.110	0.110	0.050	0	0.390	0	0.200	0.41	0.28	0.73	0.23	0.23	0.6	WSAM S-4.10:2007
	Santa Cruz	0.170	0.030	0.000	0	0.000	0.06	0.000	0.06	0.31	0.22	0.09	0.11		
	San Antonio	0.070	0.060	0.000	0	0.000	0.07	0.100	0.12	0.34	0	0.08	0.10		
	Douglas	0.500	0.070	0.330	0.19	0.570	0	0.220	0.26	0.23	0.11	0.25	0.18		
Average and standard deviation												0.16	0.18		

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WWF, 28 rue Mauverney, 1196 Gland, Switzerland. Tel. +41 22 364 9111

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