Water quality in relation to phytoplankton abundance and density of mining-impacted river in Zambales, Central Luzon, Philippines

Sazon, Rowena R. & Migo, V. P.

rrsazon1@up.edu.ph; rsazon@yahoo.com

1st International Conference on Natural Hazards & Disaster Management, Hyatt Regency Hotel, Osaka, Japan, June 1-3, 2017.

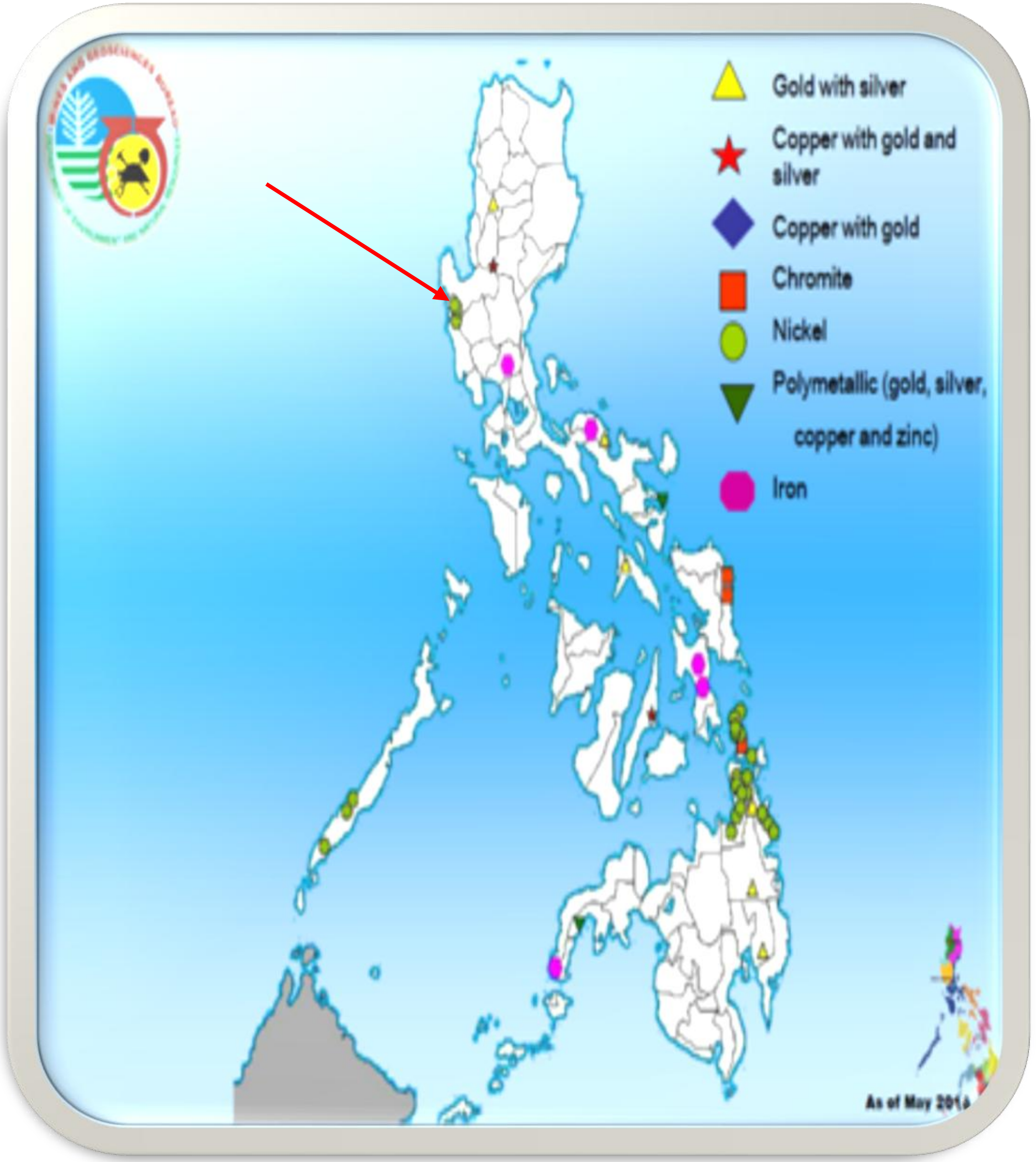
INTRODUCTION

- Philippines known for rich mineral resources (ranked 5th)

- Zambales in Central Luzon – declared mineral reservation

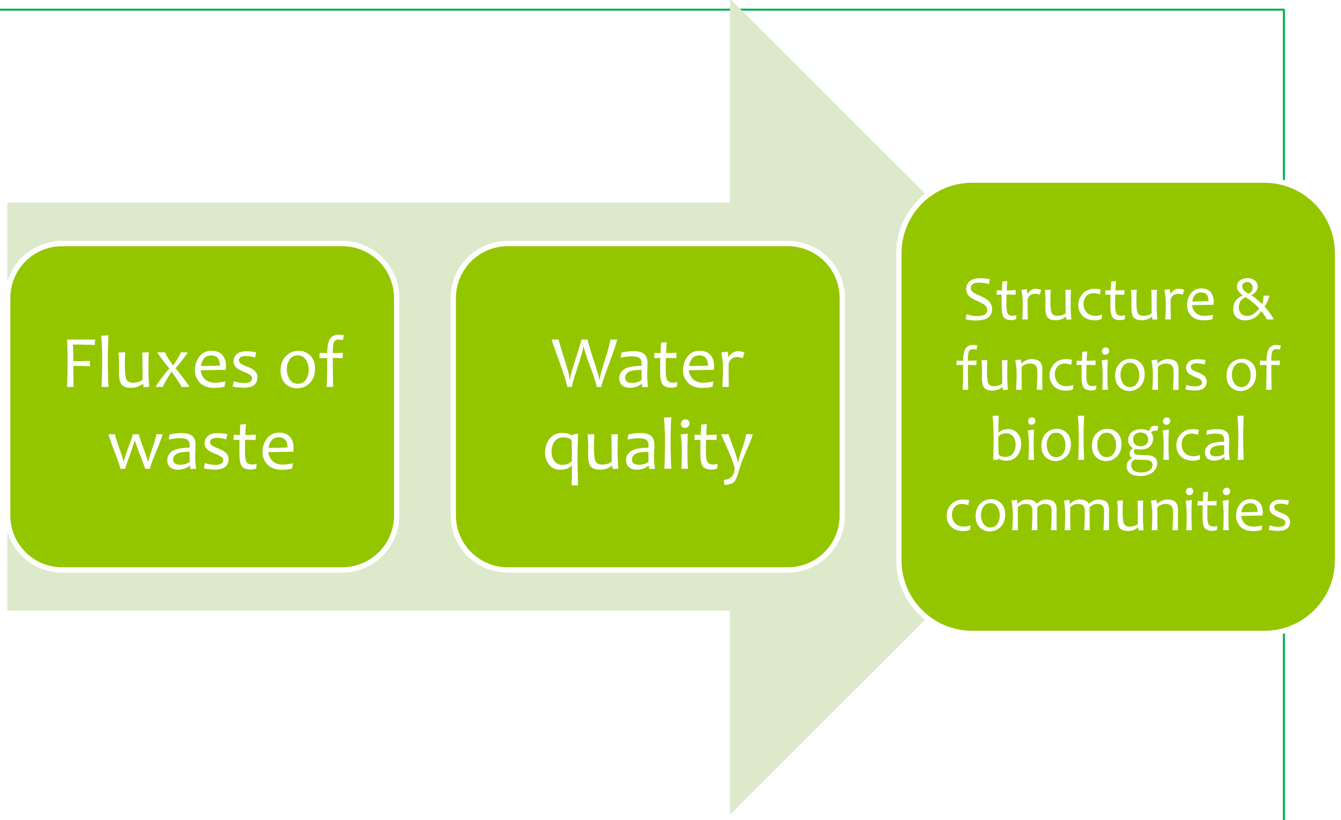
- Six MPSA's (Mineral Production Sharing Agreement) in Sta. Cruz (10,877.83 hectares or 24.81%)

- Approved commodities :
  Ni, Cr , associated
  mineral deposits



INTRODUCTION

- Open pit mining method in nickel extraction
  - removal of vegetation triggering soil erosion, runoff & sedimentation
- continuous silt deposition in water bodies & flood plains



Poor water quality can lower economic value of goods & services that support the livelihood of the community.

Objectives

General:

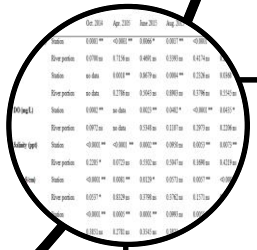
Assess the ecological condition of surface water in Zambales to aid the decision makers in the formulation of rehabilitation measures and strategies for restoration and sound utilization of its water resources.

Objectives

Assess the seasonal changes in water quality of Alinsaog River in terms of its physico-chemical characteristics (pH, temperature, dissolved oxygen, total dissolved solids, salinity, Secchi disk visibility, chemical oxygen demand, and nitrate and phosphate content);

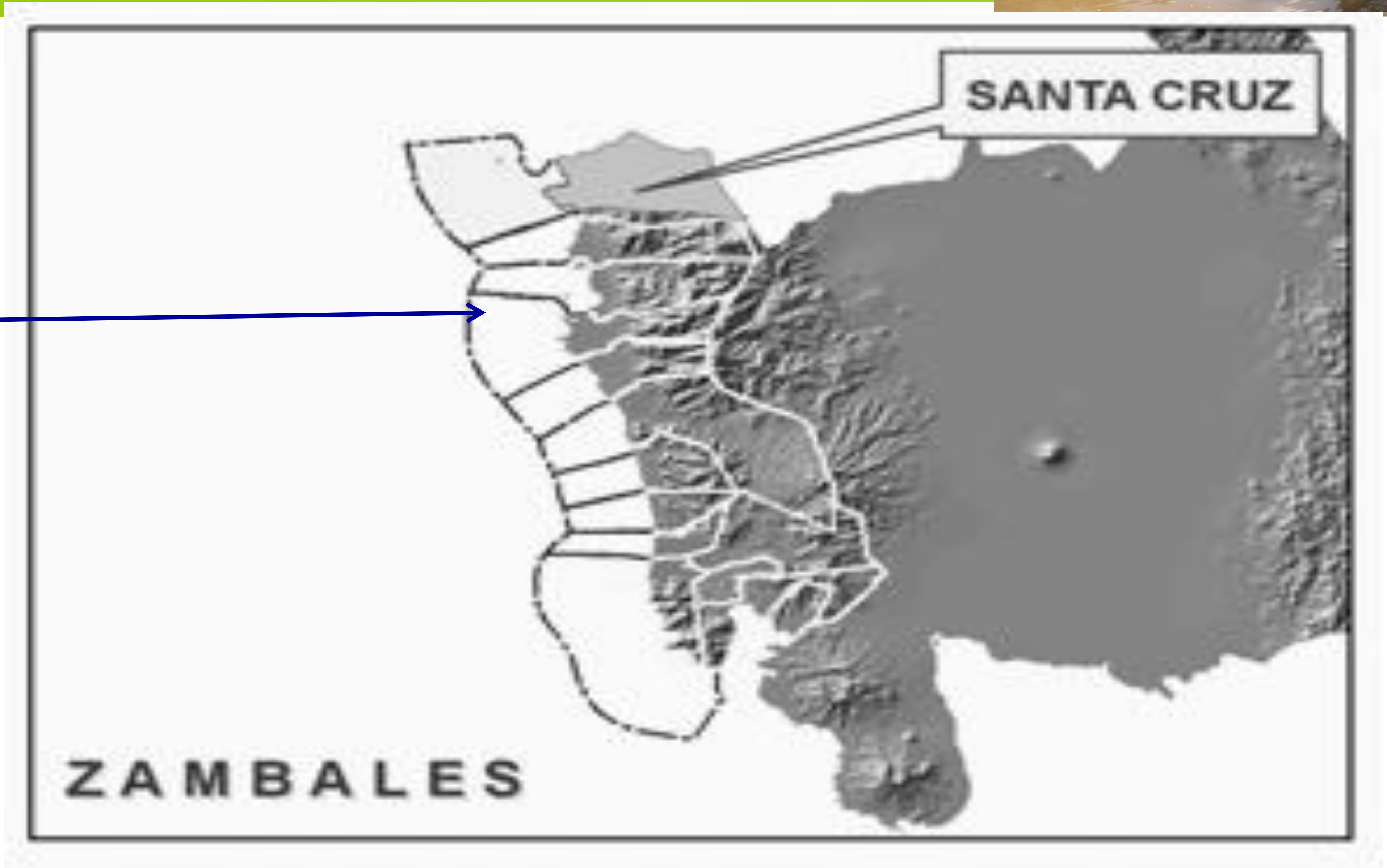
Determine the stream flow in the four sampling stations during the wet and dry season;

Determine seasonal changes in the composition, abundance and density of phytoplankton; and



Correlate water quality parameters with phytoplankton density and abundance.

THE STUDY AREA



Sta. Cruz, Zambales in Central Luzon lies at $15^{0}46'1''$ north latitude and 119^{0} 54' 32" east longitude.

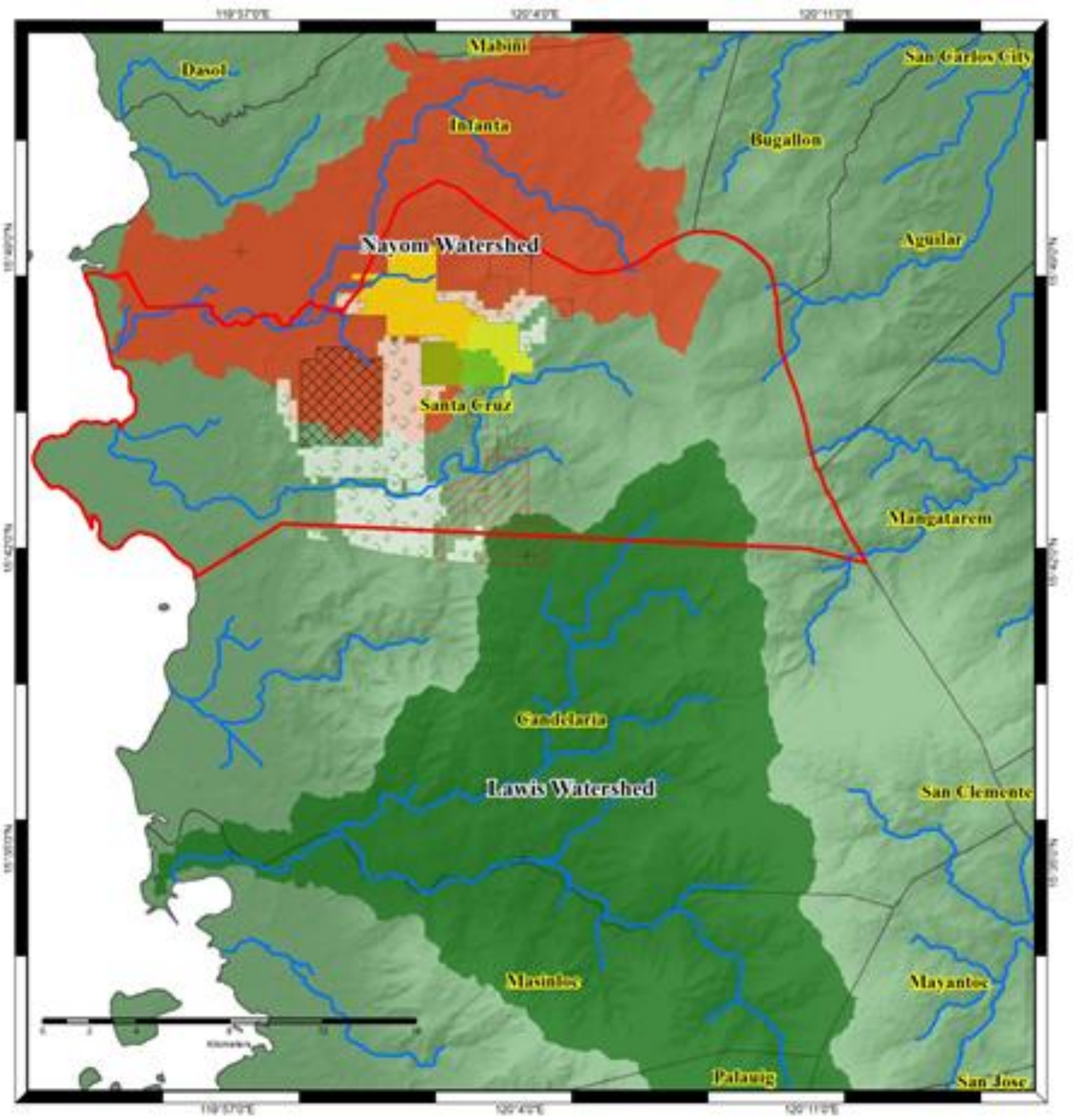
The Study Area

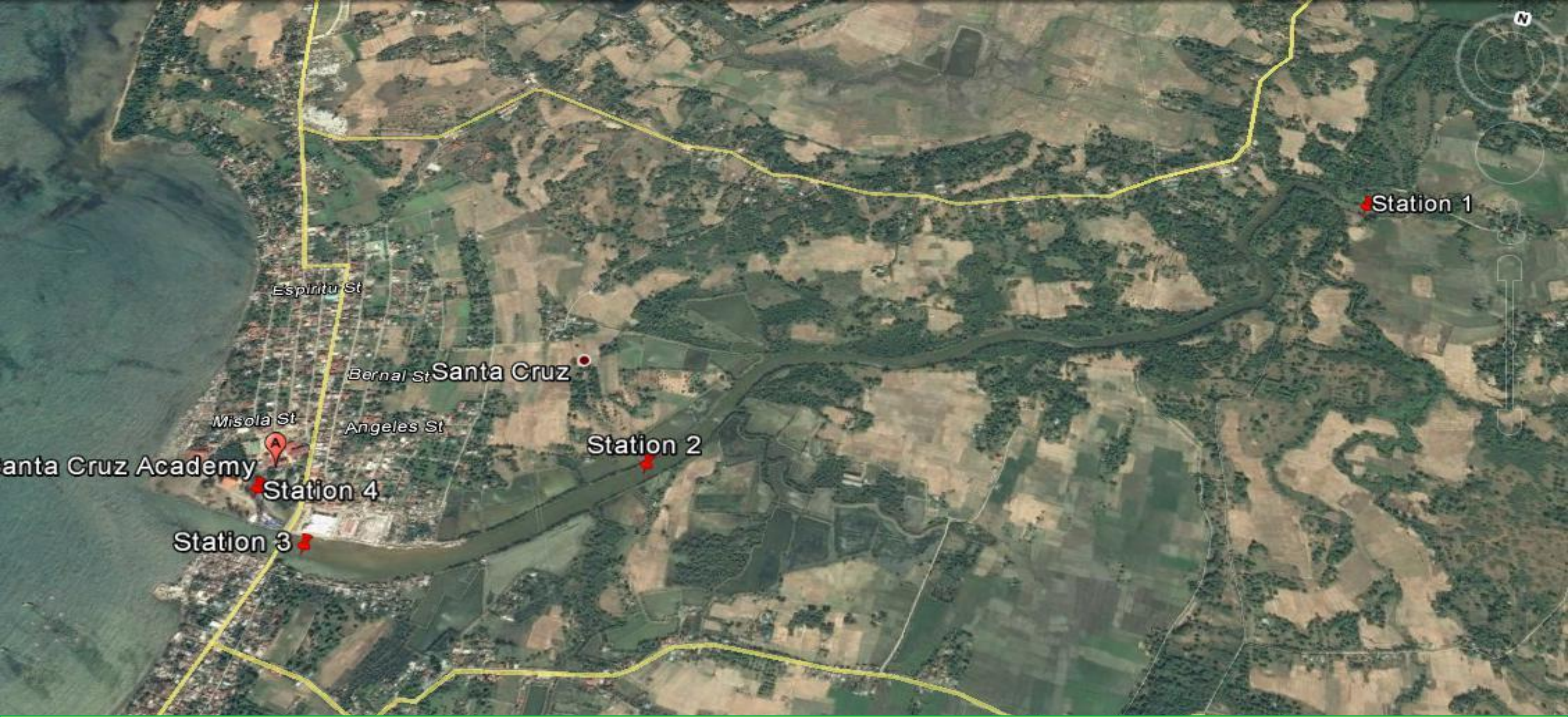
Nayom Watershed

- most mining companies operate

- four river systems draining its water into the West Philippine Sea

- Alinsaog River- heavy siltation





Land uses :

nickel & chromite mining; aquaculture & rice farming

S4: close to commercial establishments & fishing communities

METHODOLOGY

Reconnaissance survey/Characterization of study sites

- Coordination with concerned agencies
- GPS coordinates

Stream Flow measurement

- Float method as prescribed in WQ Monitoring Manual (ERDB-EMB, 2008)
- 2 transect lines laid perpendicular to the banks
- Depth measured at each transect at 4 interval points (A, B, C, D).
- Calculation of ave. depth, width, cross sectional area & stream flow

METHODOLOGY

Water Sampling & Analysis

- **Periodic water sampling** at mid-depth using improvised weighted water catcher (S1, S2, S3) & dip/pond sampler (S4)

- **Physico-chemical analysis**
  - Temperature, pH, DO (*in-situ* by Hannah HI9828/4/-2 Multiparameter WQ meter)
  - EC, TDS, salinity (Sartorius PT 20 hand-held Conductivity meter)
  - COD (open reflux method)
  - NO_3-N, PO_4 (colorimetric method)
  - mean values compared against DENR Administrative Order (AO) 34, s. 1990 & DAO 35.

METHODOLOGY

Phytoplankton sampling & identification

60L plankton sample

Sampling by bucket method (25 microns)

Filtration

Settling, filtration, collected residuum diluted with filtrate

Plankton identification & counting

1 ml aliquot in Sedgwick-Rafter counting chamber (20 mm x 50 mm)

Plankton density

Cells/ml to cells/L

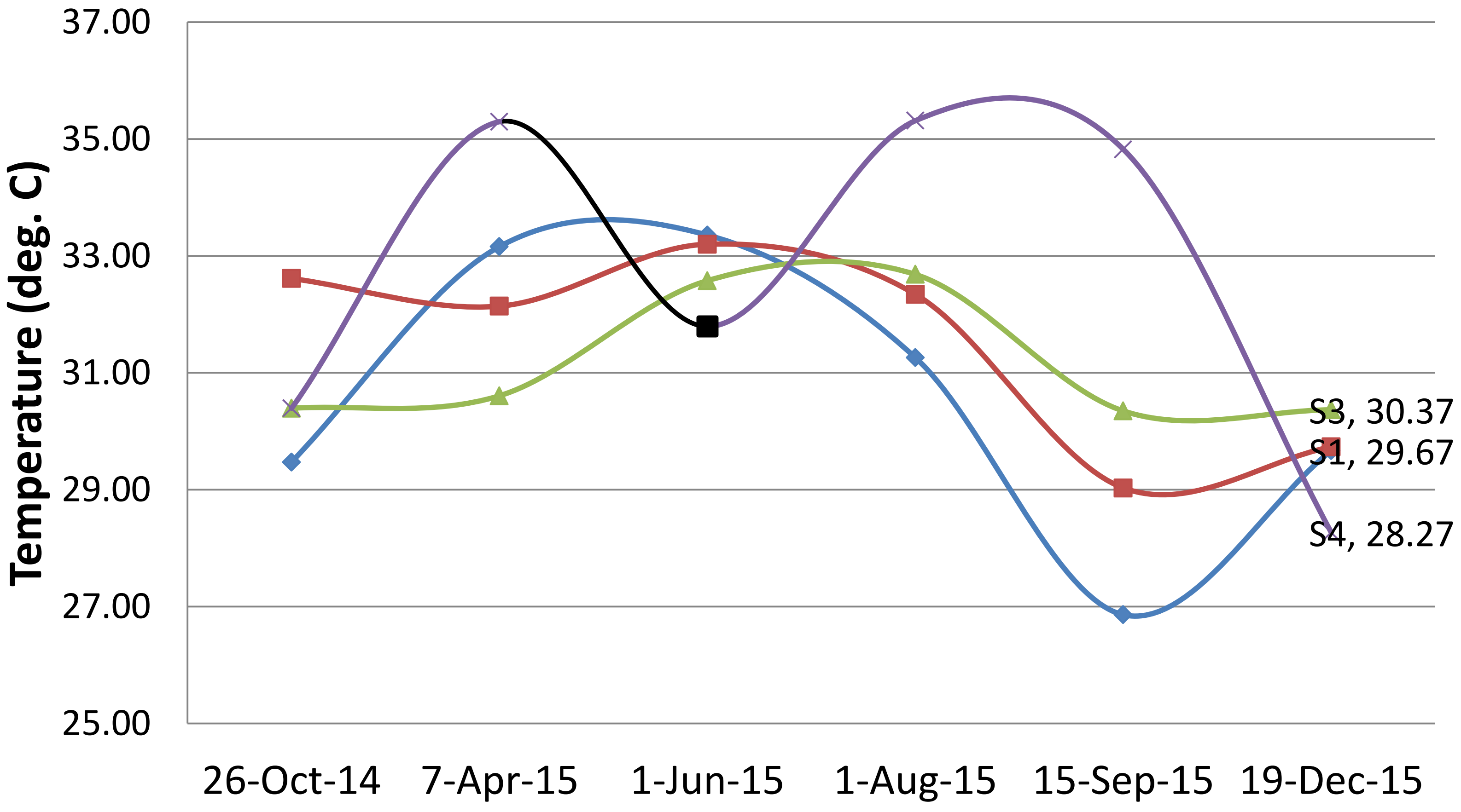
Data Analysis

- Analysis of Variance (ANOVA)
- Pearson Correlation Analysis using SAS software

RESULTS

Physico-chemical characteristics

Temperature

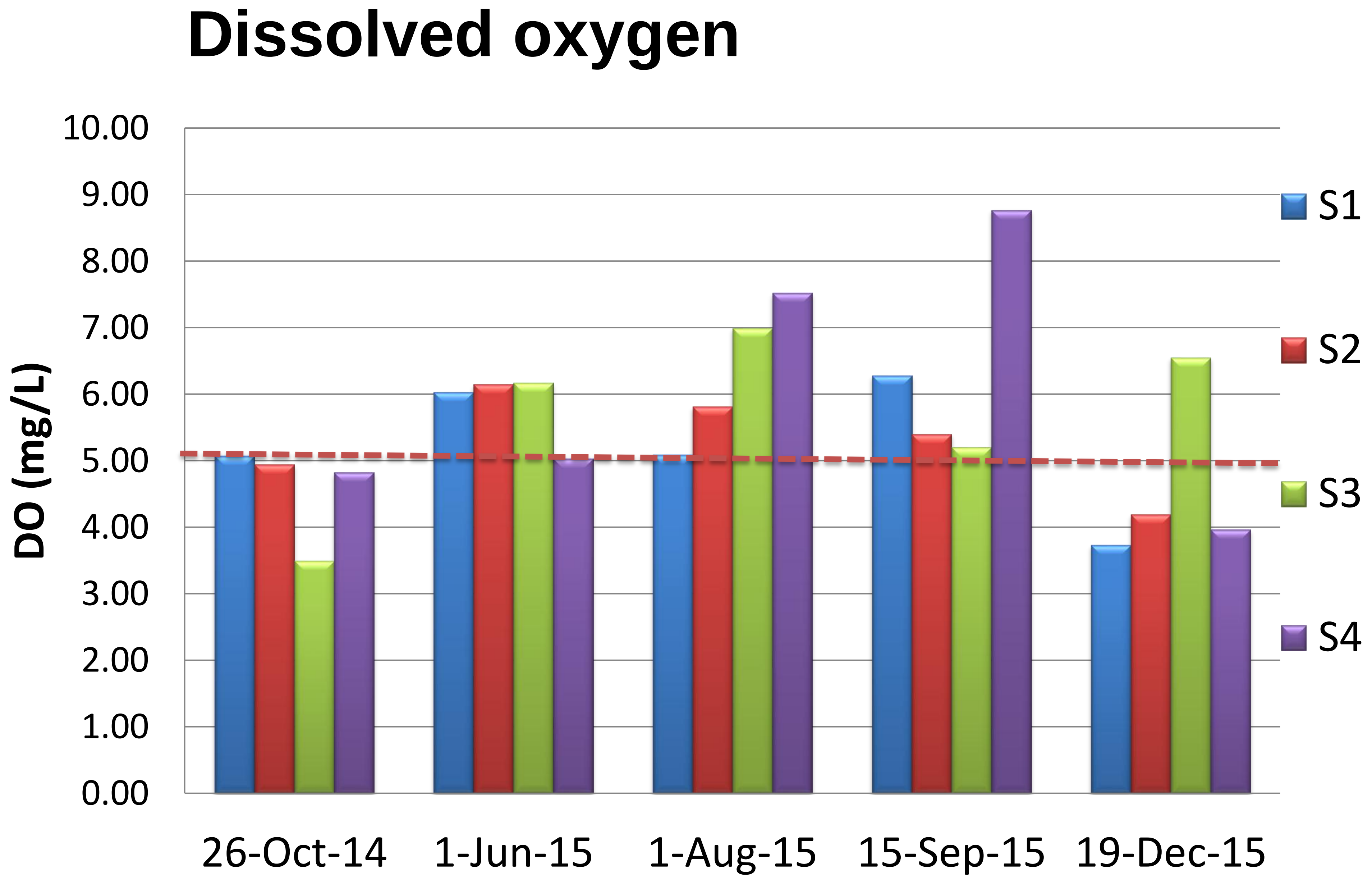


Temperature : 28.27 – 35.31 ^{0}C
Highest : April, June
Lowest : September

pH

- pH range:
  7.34 – 8.20
- DAO 34 limit :
  7.5 – 8.5
- indicates good buffering capacity of water

Physico-chemical characteristics



DO range: 3.73 – 8.77 mg/L

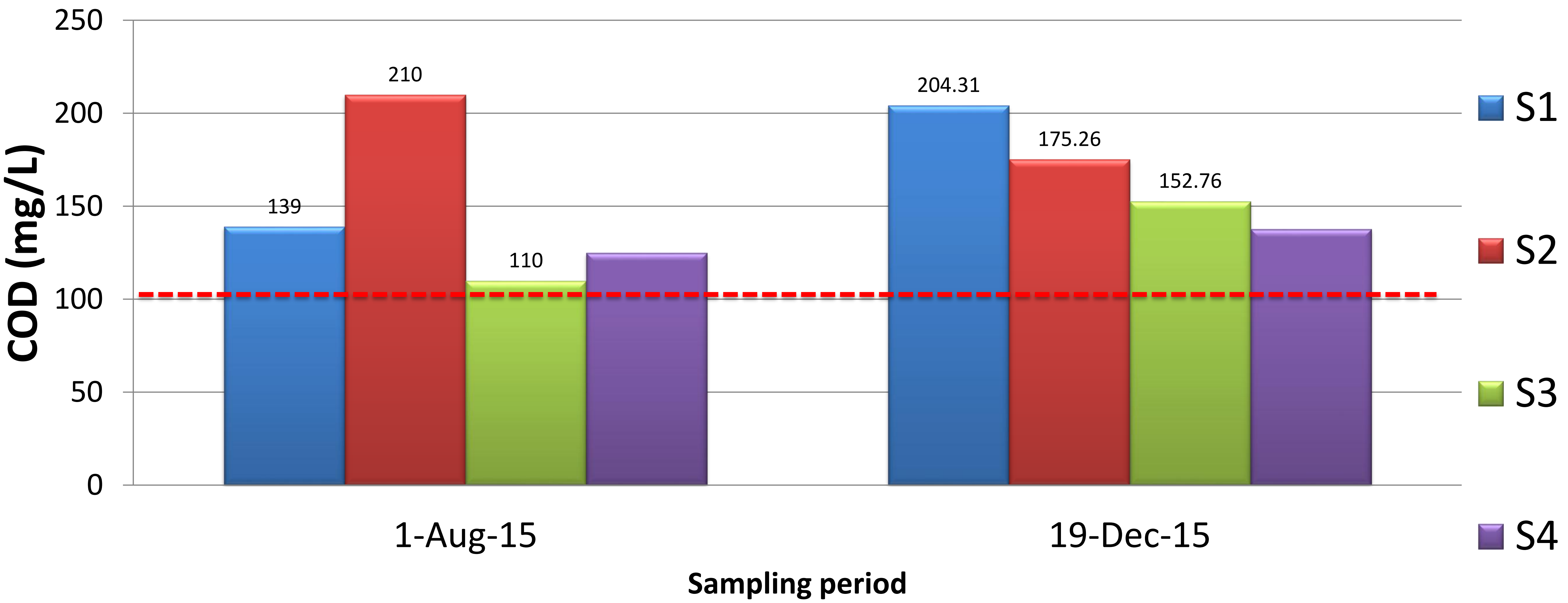
DO < 5mg/L lower [Oct. & Dec.]

Factors affecting DO:

- Temperature
- Pollution level
- Water movement

Physico-chemical characteristics

Chemical oxygen demand



COD exceeded DAO 34, s. 1990 limit (wet & dry season)

High COD contributes to lowering of DO

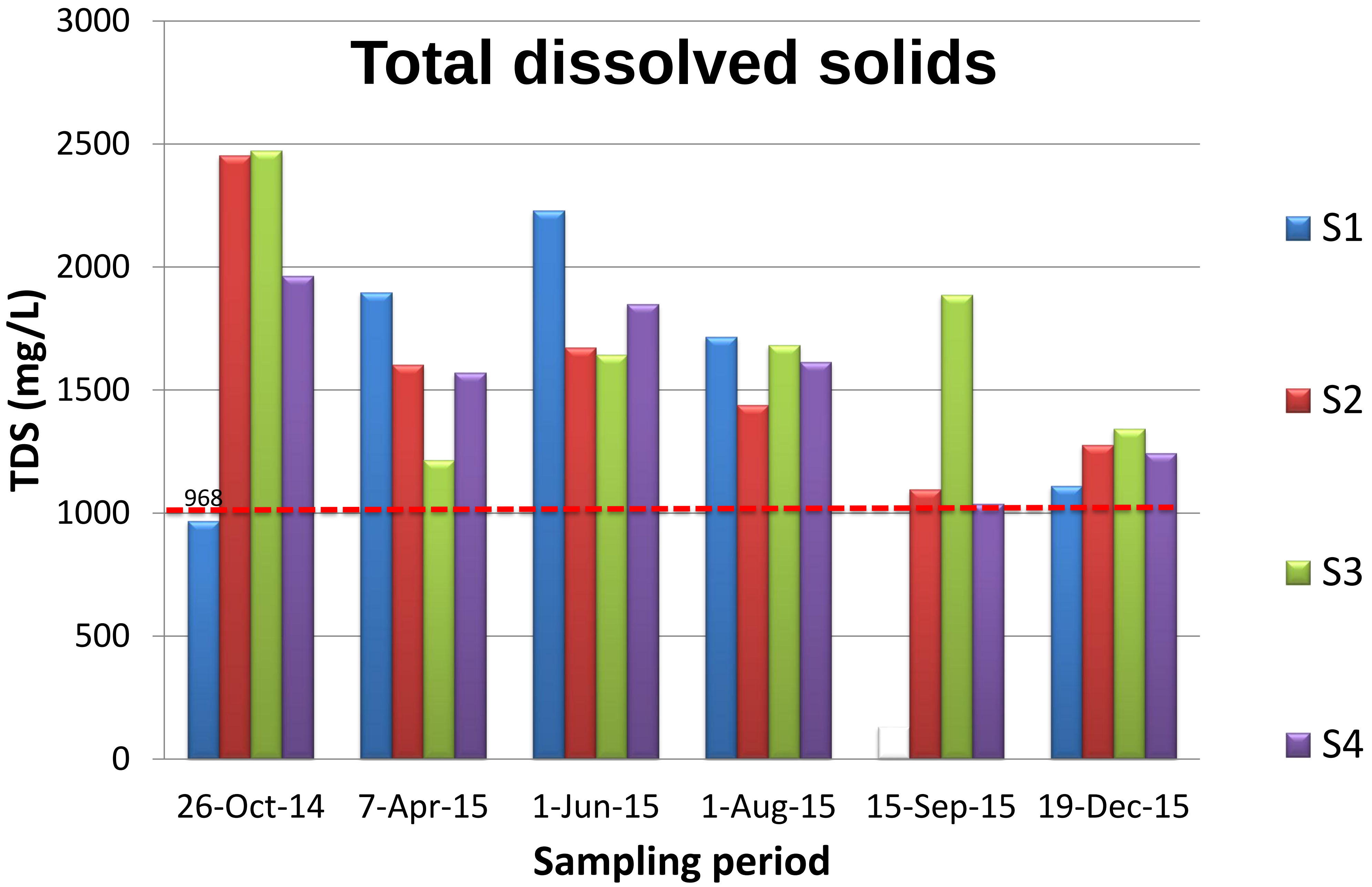
Stream flow

	WET SEASON (AUGUST)				DRY SEASON (DECEMBER)			
	S1	S2	S3	S4	S1	S2	S3	S4
Ave. width (m)	31	56.8	105	24	26	52	105	42.4
Ave. depth (m)	2.1	1.9	1.10	0.61	1.4	1.1	1.15	0.34
Ave. cross sectional area (m^2)	64.9	105.1	115.6	14.7	34.9	57.2	120.8	14.3
Stream flow (m^3/s)	11.8	18.69	22.2	**0.46**	4.5	4.9	20.5	**0.46**

Highest stream flow – S3 (downstream)
High stream flow, higher DO

Lowest flow at S4 – low DO

Physico-chemical characteristics



- TDS range: 968-2890 mg/L
- exceeded limit for Class C water
  - indication of sedimentation
  - dissolution of minerals from rocks
- Same trend with EC and salinity

Secchi disk visibility

Secchi disk visibility (cm)	Stations	SAMPLING PERIOD					
		Oct. 2014	Apr. 2105 (D)	June 2015 (W)	Aug. 2015 (W)	Sept. 2015 (W)	Dec. 2015 (D)
	S1	57.0	123.0	129.0	103.7	27.7	136.7
	S2	61.7	102.7	99.0	153.7	27.2	117.5
	S3	71.0	140.3	80.3	150.7	**30.8**	121.2
	S4	--	**39.7**	64.0	**39.0**	**41.3**	46.5

Safe optimum level : 30-45 cm (BFAR, 2013)
>60 cm : indicates inadequate primary productivity (Boyd, 2004)
<30 cm : excessive turbidity

Nutrient content

Nitrate-N & phosphate

SAMPLING STATION	NITRATE – N (mg/L)			PHOSPHATE (mg/L)		
	26-Oct-14	1-Aug-15	19-Dec-15	26-Oct-14	1-Aug-15	19-Dec-15
1	0.172 ± 0.005	0.116 ± 0.00	0.616 ± 0.007	nd	0.002 ± 0.001	**0.310 ± 0.000**
2	0.128 ± 0.032	0.051 ± 0.001	0.464 ± 0.004	nd	0.003 ± 0.002	0.003 ± 0.001
3	0.117 ± 0.004	0.065 ± 0.004	0.191 ± 0.016	nd	0.009 ± 0.002	0.005 ± 0.001
4	0.023 ± 0.011	0.064 ± 0.006	0.204 ± 0.020	nd	0.012 ± 0.002	**0.267 ± 0.001**
Class C [a]	10			0.2		
Class D [a]	--			0.4		

Phytoplankton composition

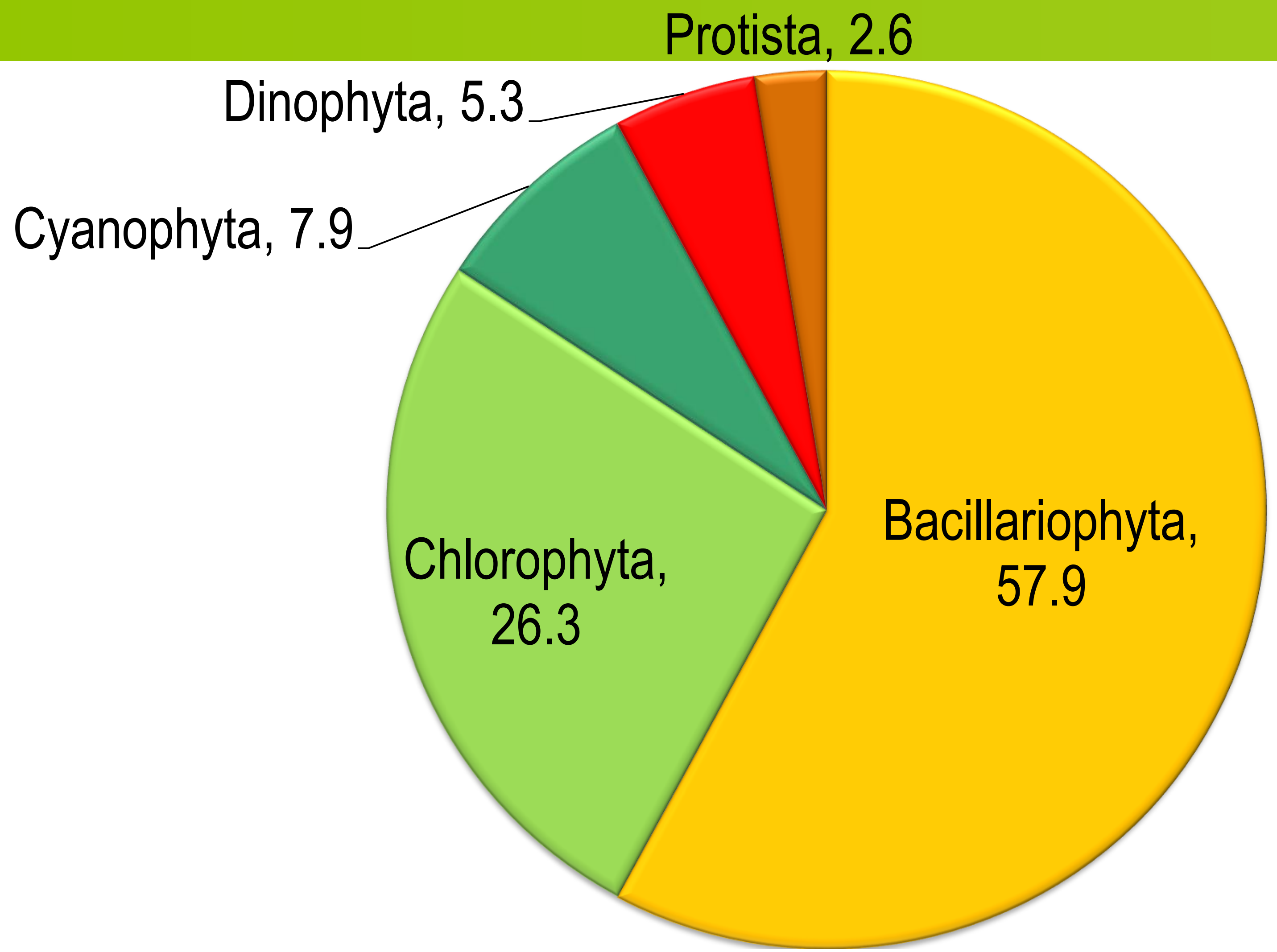
- 5 major taxonomic groups
  - Bacillariophyta
  - Chlorophyta
  - Cyanophyta
  - Dinophyta
  - Ciliates

- Fewer taxa during wet season

- 38 taxa (58% diatoms/ Bacillariophyta)

SAMPLING PERIOD	Number of taxa			
	S1	S2	S3	S4
October 2014 (D)	16	**18**	11	11
August 2015 (W)	1	3	3	**6**
December 2015 (D)	**9**	2	7	6

Phytoplankton composition



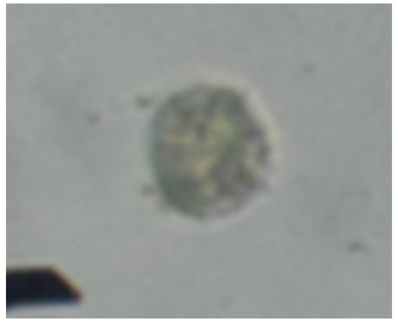
Percentage composition of phytoplankton in Alinsaog River, Sta. Cruz, Zambales (October 2014, August 2015, December 2015).

- Bacillariophyta (Diatoms) - 22 taxa
- Dominance of diatoms flora
  - indicates alkaline environment (Buzer, 1981)
  - pH range : 7.34 – 8.20

Diatoms prefer alkaline environment.
Silica needed for cell wall synthesis has increased solubility at higher pH.

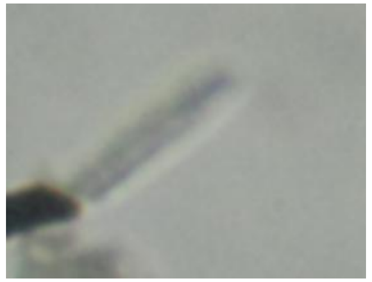
PHYTOPLANKTON TAXA	DRY SEASON				WET SEASON				DRY SEASON			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
A. Bacillariophyta												
1. *Amphora* sp.	–	–	–	–	–	–	–	–	–	–	–	+
2. *Aulacoseira* sp.	+	–	–	–	–	–	–	–	–	–	–	–
3. *Caloneis* sp.	–	–	+	–	–	–	–	–	–	–	–	–
4. *Chaetoceros* sp.	+	+	+	+	–	+	–	–	+	–	+	–
5. *Coconeis* sp.	–	–	–	–	–	–	–	+	–	–	–	–
6. *Cyclotella* sp.	+	+	+	+	–	–	–	–	+	+	+	+
7. *Cymatopleura* sp.	+	+	+	–	–	–	–	–	–	–	–	–
8. *Cymbella* sp.	–	+	–	+	–	–	–	–	–	–	–	–
9. *Fragilaria* sp.	–	–	–	–	–	–	–	–	+	–	+	–
10. *Gyrosigma* sp.	–	+	+	+	–	–	–	–	+	–	+	+
11. *Melosira* sp.	–	–	–	–	–	–	–	+	–	–	–	–
12. *Navicula* sp.	+	+	+	+	–	–	–	–	+	–	–	–
13. *Nitzschia palea*	+	+	+	–	–	–	–	–	–	–	–	–
14. *Nitzchia* sp.	–	–	–	–	–	–	+	–	–	–	–	–
15. *Pinnularia* sp.	–	–	–	–	–	–	–	–	–	–	+	–
16. *Rhoicosphenia* sp.	–	–	–	–	–	–	–	–	–	–	–	+
17. *Stauroneis* sp.	+	–	–	–	–	–	–	–	–	–	–	–
18. *Surirella elegans*	+	+	–	–	–	–	–	–	–	–	–	–
19. *Surirella ovalis*	–	–	–	–	–	–	–	+	–	–	–	–
20. *Surirella robusta*	+	+	–	+	–	–	+	+	+	–	–	–
21. *Surirella viridis*	+	+	+	–	–	+	–	–	–	–	–	–
22. *Synedra* sp.	+	+	+	–	–	–	–	–	+	–	+	–
B. Chlorophyta												
23. *Chodatella* sp.	–	+	+	–	–	–	–	–	–	–	–	–
24. *Cladophora* sp.	–	–	–	–	–	–	–	–	–	–	–	–
25. *Closterium* sp.	–	–	–	–	–	–	–	+	–	–	–	–
26. *Cosmarium contractum*	+	+	–	+	–	–	–	–	–	–	–	–
27. *Eudorina* sp	–	–	–	–	–	–	+	–	–	–	–	–
28. *Microspora* sp.	+	–	–	–	–	–	–	–	–	–	–	–
29. *Monoraphidium* sp.	–	+	–	–	–	–	–	–	–	–	–	–
30. *Oocystis* sp.	–	–	–	+	–	–	–	–	–	–	–	–
31. *Sphaerocystis* sp.	+	+	+	+	–	–	–	–	+	–	–	–
32. *Spirogyra* sp.	+	+	–	–	+	–	–	–	–	–	–	–
C. Cyanophyta												
33. *Lyngbya* sp.	+	–	–	–	–	–	–	–	–	–	–	–
34. *Nostoc* sp.	–	+	–	+	–	–	–	–	–	–	–	–
35. *Oscillatoria* sp.	–	+	–	+	–	–	–	+	–	–	–	–
D. Dinophyta		–	–	–	–	–	–	–	–	–	–	–
36. *Pyrodinium* sp.	–	–	–	–	–	+	–	–	–	–	–	–
37. *Peridinium* sp.	–	–	–	–	–	–	–	–	+	+	+	+
E. Protista		–	–	–	–	–	–	–	–	–	–	–
38.Tintinnid ciliate	–	–	–	–	–	–	–	–	–	–	–	+
Total no. of taxa	**16**	**18**	**11**	**11**	**1**	**3**	**3**	**6**	**9**	**2**	**7**	**6**

Phytoplankton composition

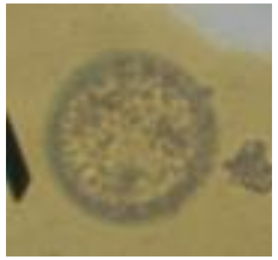


Sphaerocystis sp.- stress survivor species

Cyclotella, *Synedra* and *Scenedesma*, *Navicula*, *Nitzschia* sp. & *Oscillatoria* sp. - indicators of organic pollution



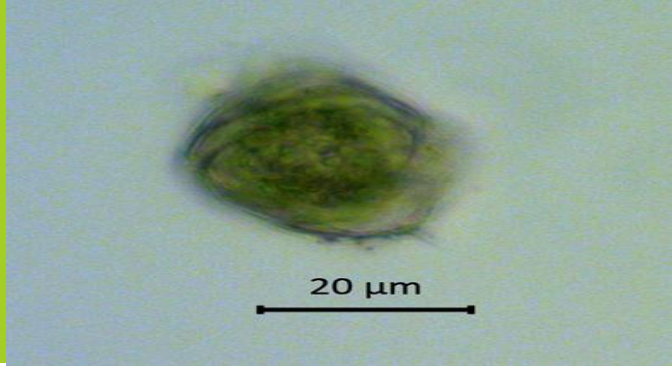
Navicula sp. - indicator of excess siltation



Cyclotella species - indicator of oligotrophy

Melosira and *Microcystis* - pollution resistant species

Phytoplankton density



Phytoplankton density on four sampling stations at different periods.

SAMPLING PERIOD	DENSITY (cells/L)				
	S1	S2	S3	S4	Total
October 2014 (dry)	11.7	452.1	13.2	12.4	489.3
August 2015 (wet)	3.5	2.5	3.6	38.2	47.8
December 2015 (dry)	**111,987.**	**104,395**	**87,265**	74.2	303,721

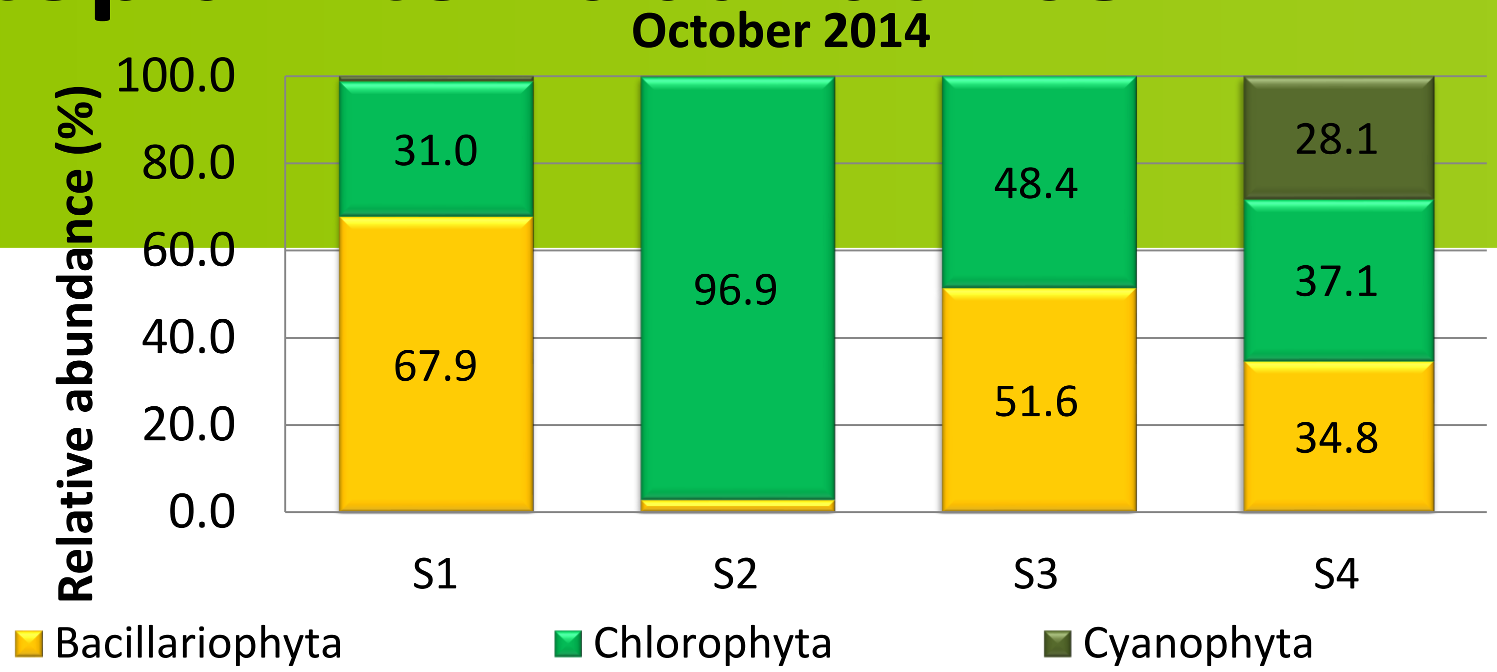
Wet season - fewer taxa, lower density of phytoplankton

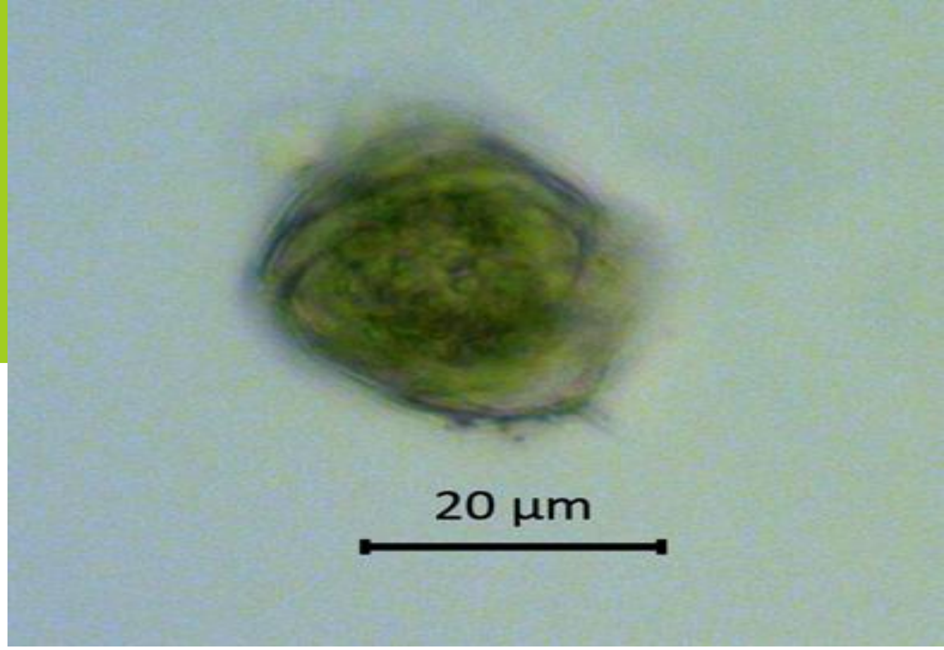
- presence of *Pyrodinium* sp. but at low density

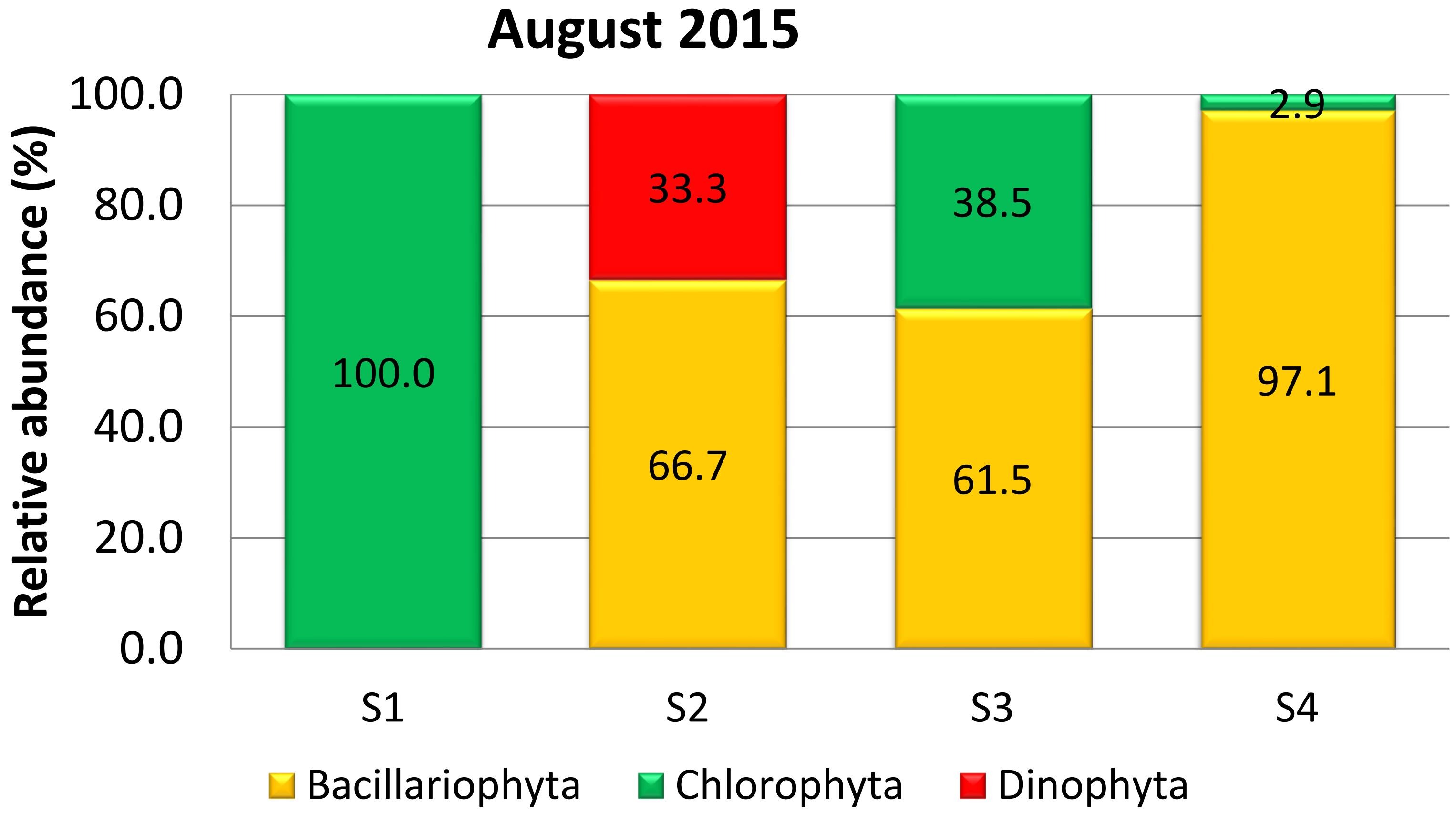
After flooding (Koppu)

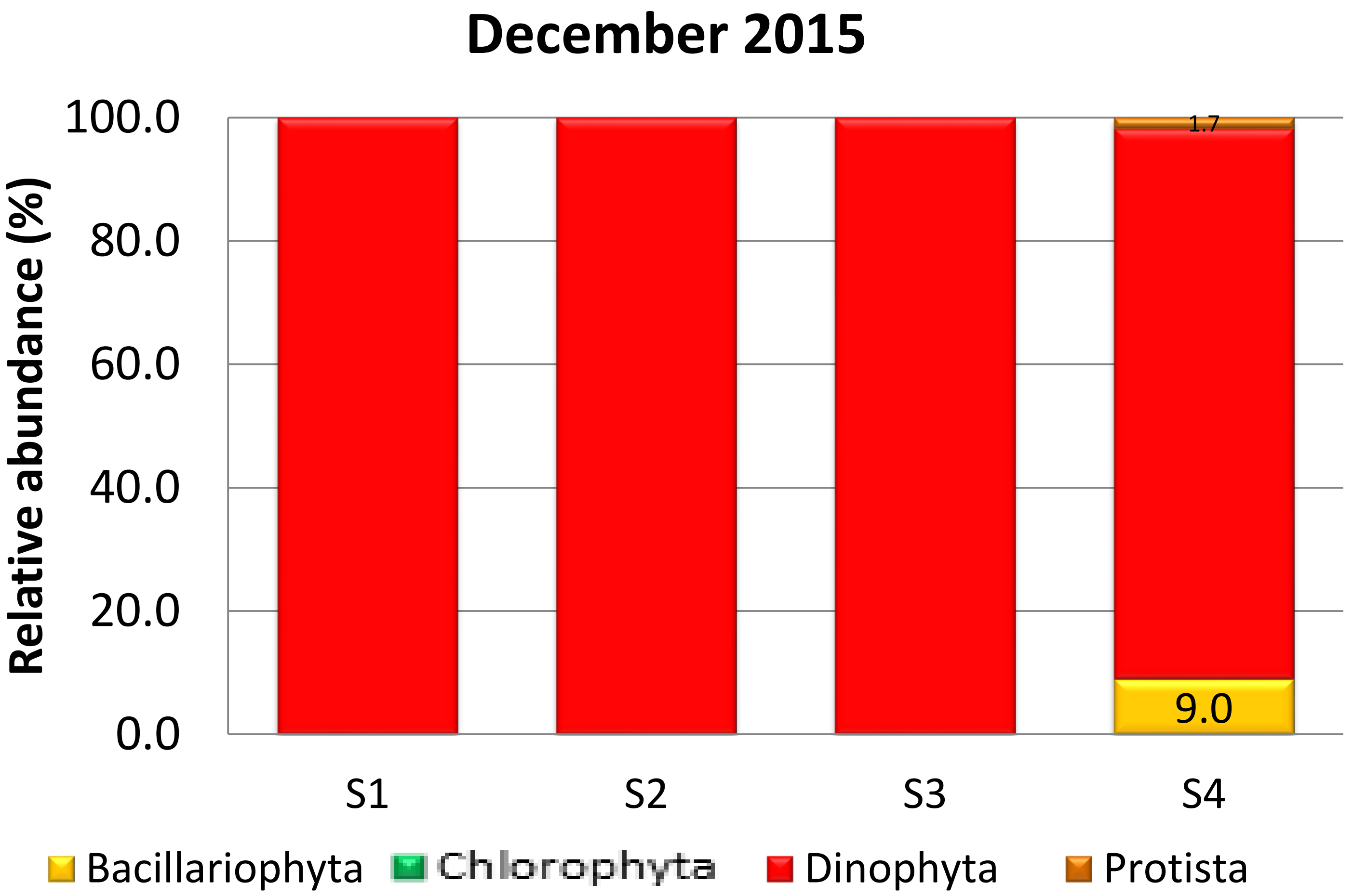
- high density of dinoflagellates (*Peridinium* sp.)   111, 982 cells/L

Phytoplankton abundance









Correlation between WQ variables and phytoplankton

- Cyanophyta density with TDS, EC, and salinity (+)
  - TDS contains minerals
- Dinoflagellates density correlated with EC (-)
- Diatoms abundance correlated with pH (+)
  - Silica is highly soluble at alkaline pH
- Total density of phytoplankton correlated with EC (-)
  - High EC, high TDS, reduced light penetration, lower photosynthetic activity

PHYTOPLANKTON GROUP		PHYSICO-CHEMICAL PARAMETERS						
		Temp.	pH	DO	Salinity	EC	TDS	Water depth
Bacillario phyta	Density	0.50067	0.2389	0.49432	0.2311	0.2157	0.2324	-0.5647
	Abundance	0.5170	0.7101*	0.5238	0 .0545	0.1038	0.0749	-0.1031
Chlorophyta	Density	0.1811	0.1496	-0.0647	0.3538	0.3188	0.3466	0.1795
	Abundance	0.2018	0.0990	-0.1046	0.3955	0.3976	0.3983	0.5591
Cyanophyta	Density	0.5004	---	-0.1014	0.6294*	0.6051*	0.6257 *	-0.2111
	Abundance	0.4615	---	-0.0882	0.5521	0.5359	0.5500	-0.2534
Dinophyta	Density	-0.4177	-0.4739	-0.2218	-0.5351	-0.6005*	-0.5559	-0.0771
	Abundance	-0.6195	-0.6390	-0.2898	-0.4497	-0.4859	-0.4668	-0.3149
Protista	Density	-0.4568	-0.4650	-0.2941	0.1903	0.2544	0.1865	-0.5541
	Abundance	-0.4568	-0.4650	-0.2941	0.1903	0.2544	0.1865	-0.5541
Total density		-0.4173	-0.4739	-0.2220	-0.5344	-0.5999 *	-0.5552	-0.0767

CONCLUSION

- The river in general is not in healthy state (DO, COD and TDS exceeded the DAO standard limit).
- Stream flow influences other water quality parameters
- Composition and density of plankton species indicated poor water quality of the study area.
- Predominant plankton - adapted to grow at low N and P & high organic pollution; stress tolerant; pollution resistant
- Large scale mining operations by open pit method coupled with unfavorable weather conditions & insufficient interventions caused heavy siltation in the river system leading to poor water quality and reduced primary productivity.

RECOMMENDATIONS

- Conduct regular monitoring & assessment of water quality of rivers affected by siltation;

- Formulation & implementation of regulatory/intervention measures addressing point source of pollution;

- Enforce strict compliance of the contract holders on their ECC commitment;

- Policy review (granting of MPSA, etc.);

- Rehabilitation of the rivers with thick silt deposits; and

- Economic valuation of the social cost and benefits of mineral resource exploitation.

MARAMING SALAMAT!
MABUHAY!

Acknowledgement

Accelerated Science and Technology Human Resource Development Program - National Science Consortium (ASTHRDP-NSC) and Student Research Support Fund (SRSF) of the Department of Science and Technology (DOST)