Lake Salinity Levels & Eutrophication

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Outline

- Natural vs. cultural eutrophication
- Sources of eutrophication
- Spatial distribution-eutrophic & hyper-eutrophic lakes, AB
- Metrics – Chlorophyll-a, TDS, Sp. Cond., R^2
- Looking at data – eutrophic lakes, saline lakes
- Verifying Relationships
  - Total P & Chlorophyll-*a*
  - Total N & Chlorophyll-*a*
  - Salinity & Chlorophyll-*a*
  - Salinity & Total P
  - Salinity & Total N
- Conclusions

Essential Macro Nutrients

- Nitrogen - N
- Phosphorus - P
- Potassium - K

Eutrophication

- Natural eutrophication and lake aging occurs over centuries, and results from natural sources of nutrients and sediments.
- Cultural eutrophication and lake ageing occurs over decades, and results from human-induced urban runoff, sewage effluent, industrial waste, fertilizers, pesticides, and excess sediments.

http://www.waterencyclopedia.com/Hy-La/Lake-Management-Issues.html

Sources of Cultural Eutrophication

- Natural runoff (nitrates and phosphates)
- Discharge of detergents (phosphates)
- Discharge of treated municipal sewage (nitrates and phosphates)
- Dissolving of nitrogen oxides from internal combustion engines and furnaces
- Manure runoff from feedlots (nitrates, phosphates, ammonia)
- Runoff from streets, lawns, and construction lots (nitrates and phosphates)
- Runoff and erosion (from cultivation, mining, construction and poor land use)
- Nitrogen produced by cars and factories
- Discharge of untreated sewage (nitrates and phosphates)
- Discharge of detergents (phosphates)

http://zolushka4earth.files.wordpress.com/2010/08/culturaleutroph.jpg

http://sunsite.ualberta.ca/Projects/Alberta-Lakes/images/characteristics/char_fig01.jpg

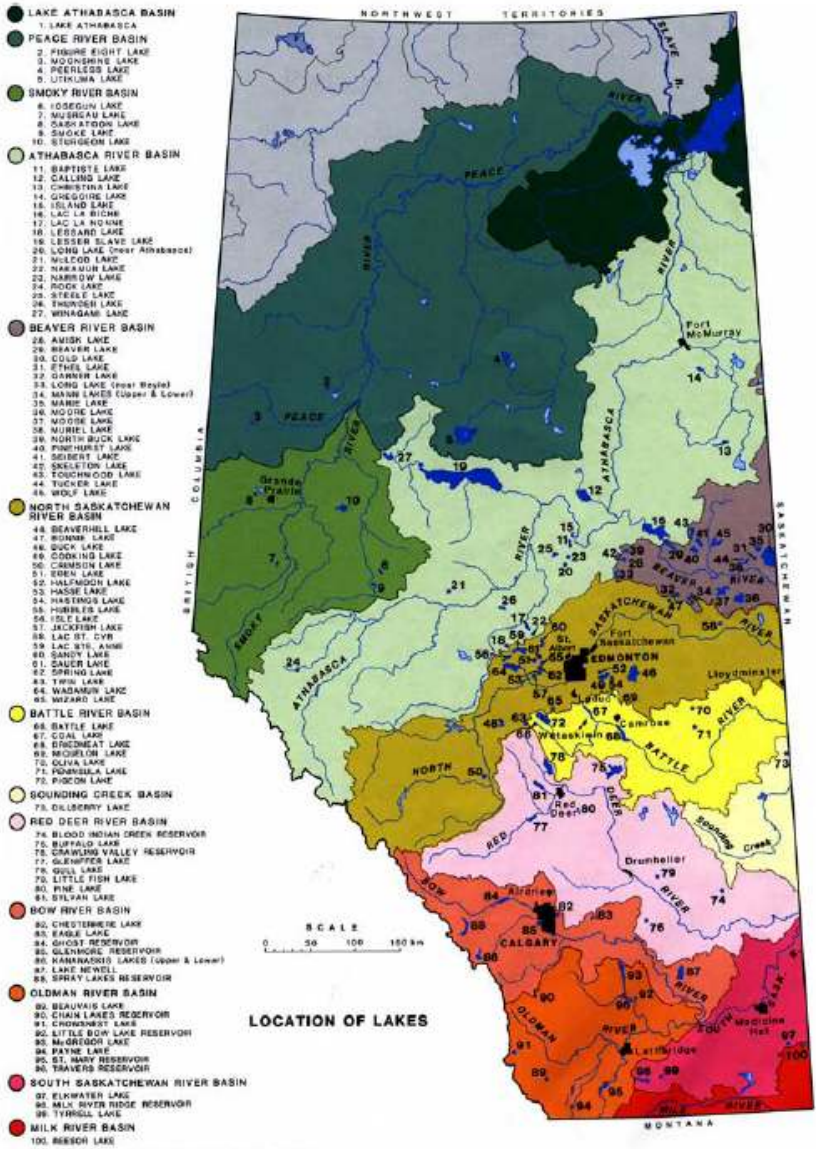
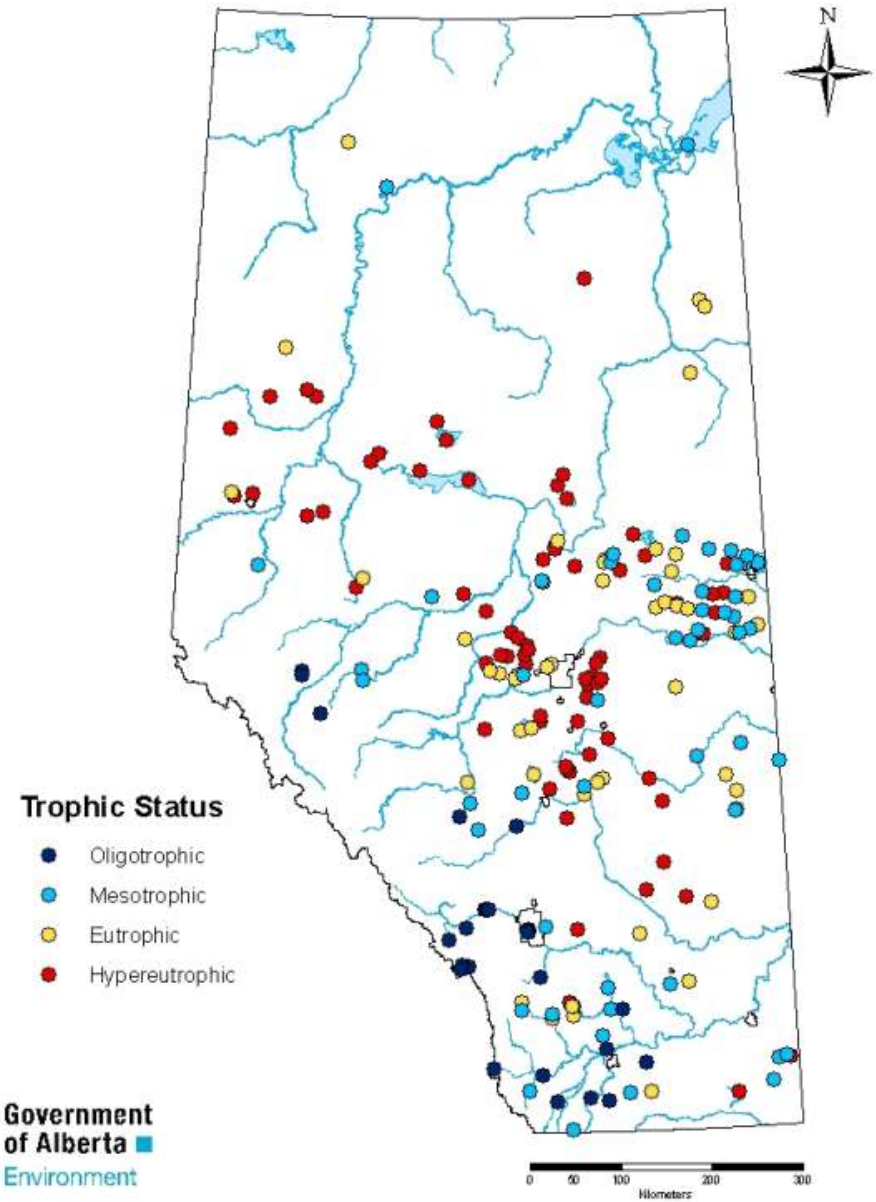


Figure 1. Map of lake locations in the *Atlas of Alberta Lakes*.

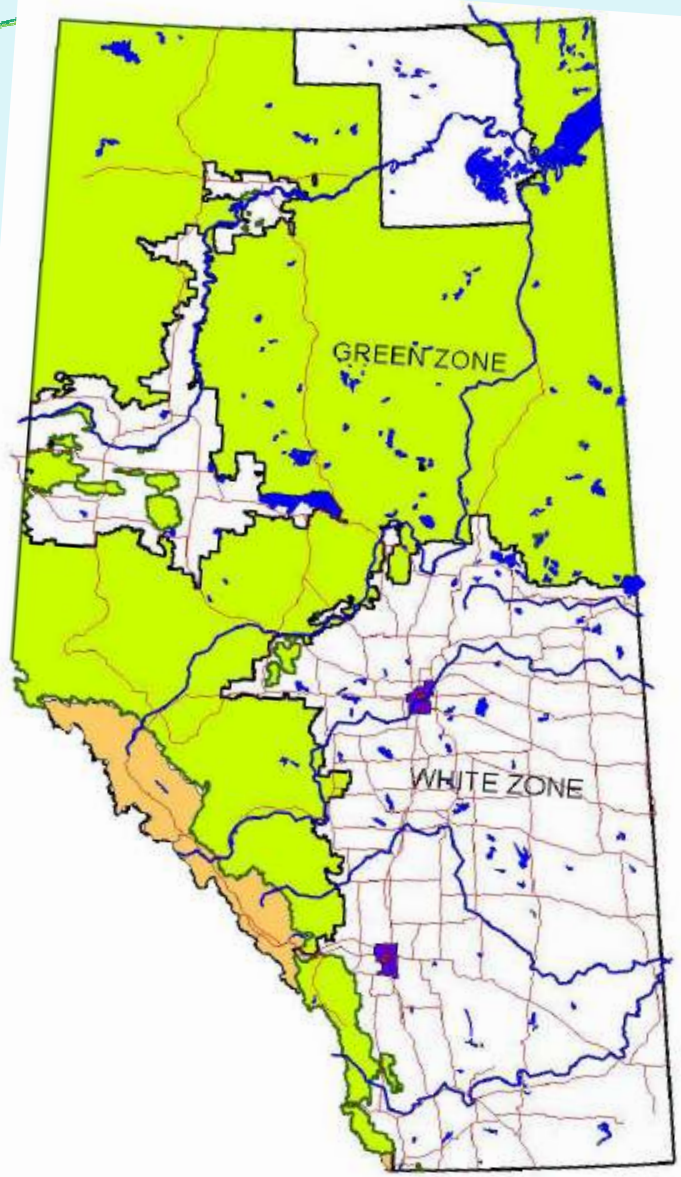
TROPHIC STATE OF ALBERTA LAKES

Based on Average Summer (May-September) Total Chlorophyll-a Concentrations

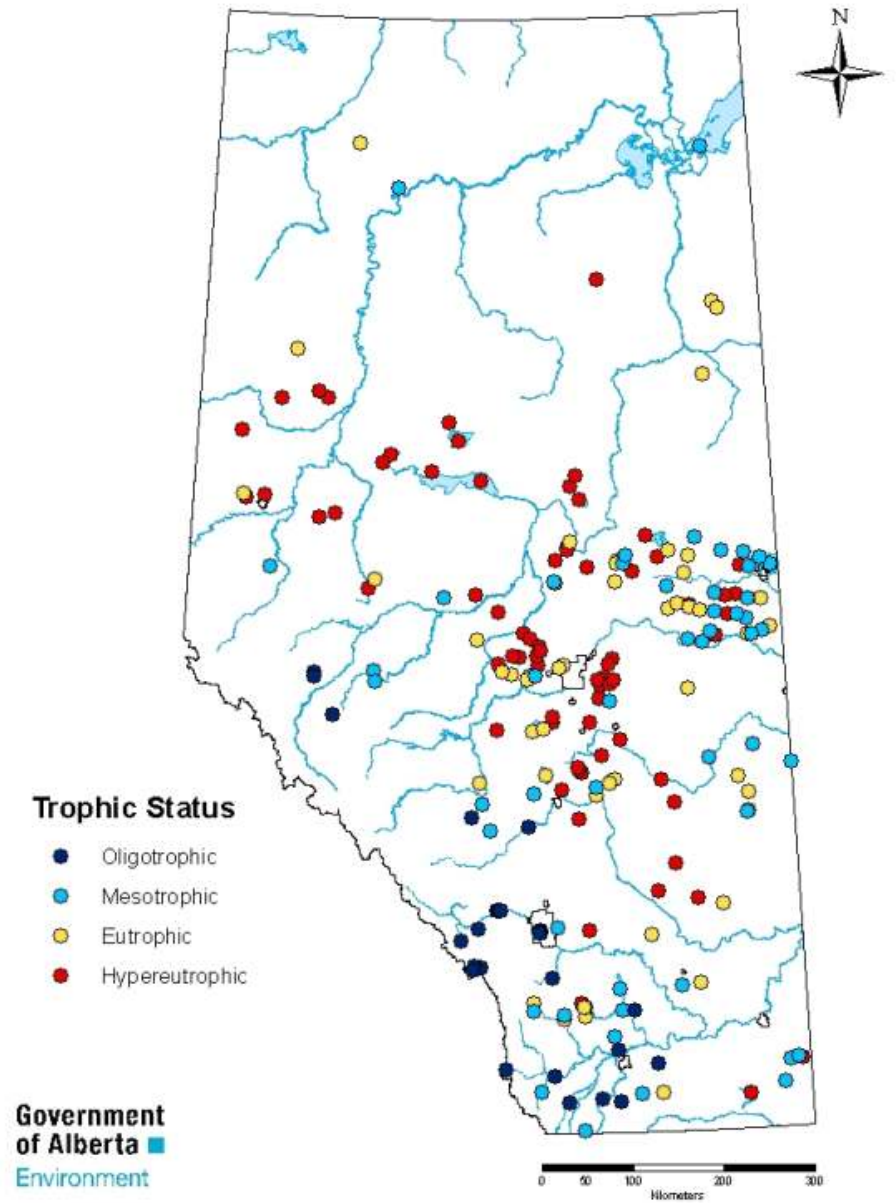


Government of Alberta
Environment

Three most recent years of data was used to calculate trophic status
Created July 2009



GREEN ZONE / WHITE ZONE



Chlorophyll-*a* concentration (µg/L)

- **green** pigmentation found in all plants including microscopic **algae**
- An estimate of **algal biomass** - surface waters
- Indicator of **trophic** levels - surface waters
  - Oligotrophic - < 8 µg/L
  - Mesotrophic – 8-25 µg/L
  - Eutrophic – 26-75 µg/L
  - Hyper-eutrophic > 75 µg/L

Salinity – Total Dissolved Solids

- TDS - All solids (usually mineral salts) that are dissolved in water
- TDS concentration (mg/L)
  - Freshwater lakes - < 500 mg/L (arbitrary boundary)
  - Slightly saline lakes – 500-1000 mg/L
  - Moderately saline lakes – 1000-5000 mg/L
  - Saline lakes - > 5000 mg/L

Salinity – Specific Conductance

- Dissolved salts in water transmit electrical current (**electrical conductivity**, EC)
- Measurement – dS/m, µS/cm
- **Water temperature** affects electrical conductivity
- **Specific conductance** – EC standardized to 25°C
  - Freshwater – 0 - 1,300 µS/cm
  - Brackish – 1,301 - 28,000 µS/cm
  - Salty - > 28,000 µS/cm

Symbols

- N – Nitrogen
- P – Phosphorus; TP = Total Phosphorus
- HCO_3^{-1} – bicarbonate
- CO_3^{2-} – carbonate
- Mg^{2+} – Magnesium
- Na^{+} – Sodium
- K^{+} – Potassium
- Cl^{-} - Chloride
- SO_4^{2-} – Sulfate
- Ca^{2+} – Calcium

Looking at some AB Lakes

- Data Source - Atlas of Alberta Lakes
- Data are from mid 80s

Lakes	Ghost	Kanaskis	Buffalo (M)	Sylvan	Miquelon	Pigeon	Moonshine	Pine	Pinehurst	Gull	Baptiste (S)	La Nonne	Winagami
Watershed	Bow	Bow	Red Deer	Red Deer	Battle	Battle	Peace	Red Deer	Beaver	Red Deer	Athabasca	Athabasca	Athabasca
	Oligotrophic		**Mesotrophic**			**Eutrophic**					**Hyper-eutrophic**		
Salinity status	Fresh water	Fresh water	Moderately saline	Fresh water	Saline	Fresh water	Fresh or very slightly saline?	Fresh or very slightly saline?	Fresh water	Slightly saline	Fresh water	Fresh water	Fresh water
Data year	1985	1984	1983	1986	1983	1983-84	1986	1984	1986	1983	1986	1988	1986
Chl-a µg/L	2	2.9	**4.9**	3.7	**4.6**	11.6	**6.8**	**26.3**	14.6	**7.3**	**24**	**55.5**	**67**
Sp Cond µS/cm	277	168	**2357**	597	**6530**	283	**719**	**726**	280	**1144**	343	314	453
TDS mg/L	152	90	1595	338	5402	155	446	450	152	713	184	176	266
TP µg/L	7	5	**59**	20	**131**	29	**54**	**56**	46	**36**	**49**	**168**	**223**
TN µg/L	432	273	**2807**	---	**5696**	910	__	**1302**	**1213**	**1540**	**1013**	**2224**	---
pH	7.3-7.9	7.1-8.6	8.9-9.3	8.9-9.0	9.3-9.4	8.2-8.6	7.6-8.4	7.9-8.9	7.9-8.7	9-10.1	7.6-8.8	8.1-9	8.3-8.9

TDS mg/L: freshwater <500, slightly saline 500-1000, moderately saline 1000-5000, saline >5000

Major Ions

Lakes	Ghost	Kanaskis	Buffalo	Sylvan	Miquelon	Pigeon	Moonshine	Pine	Pinehurst	Gull	Baptiste	La Nonne	Winagami
	Oligotrophic		Mesotrophic			Eutrophic					Hyper-eutrophic		
1. HCO_3 mg/L	137	98	**922**	354	**1083**	343	184	179	170	**603**	191	164	185
2. CO_3 mg/L	<1	1	**134**	21	**306**	<4	2	23	<6	77	<4	<9	<5
3. Mg mg/L	10	4	**53**	37	**206**	10	36	25	13	**60**	11	10	24
4. Na mg/L	2	0.3	**501**	64	**1473**	16	48	**108**	8	**183**	21	17	13
5. K mg/L	0.4	0.2	37	7	**110**	5	6	10	4	18	3	10	10
6. Cl^- mg/L	1	0.5	12	<1	**99**	<1	<1	6	<1	4	2	3	2
7. SO_4 mg/L	31	7	**394**	16	**2413**	<5	**209**	**84**	<1	**67**	15	14	**79**
8. Ca mg/L	37	29	9	18	14	26	**53**	23	32	8	35	33	42

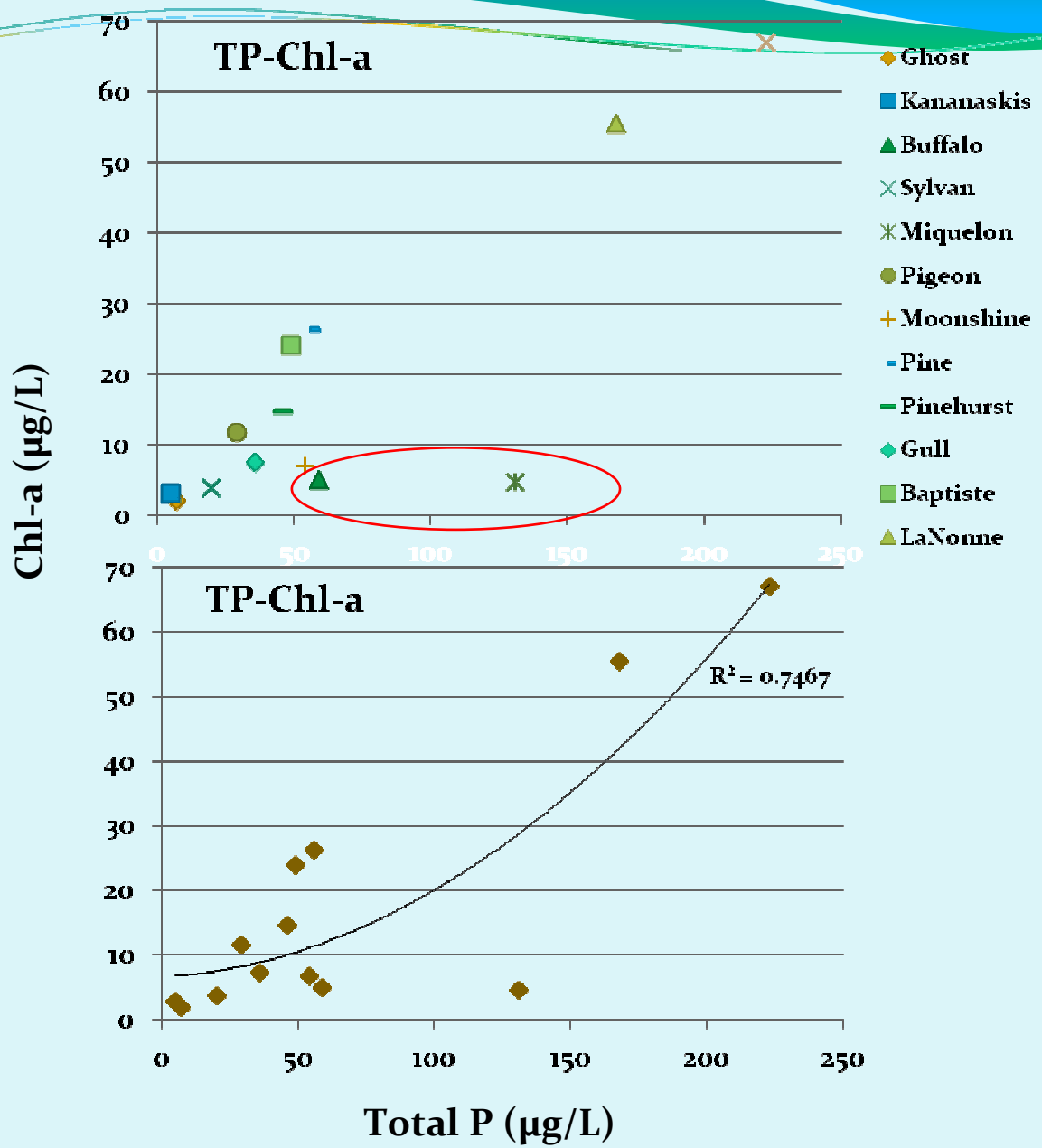
1. Bicarbonate, 2. carbonate, 3. magnesium, 4. sodium, 5. potassium, 6. chloride, 7. sulfate, 8. calcium

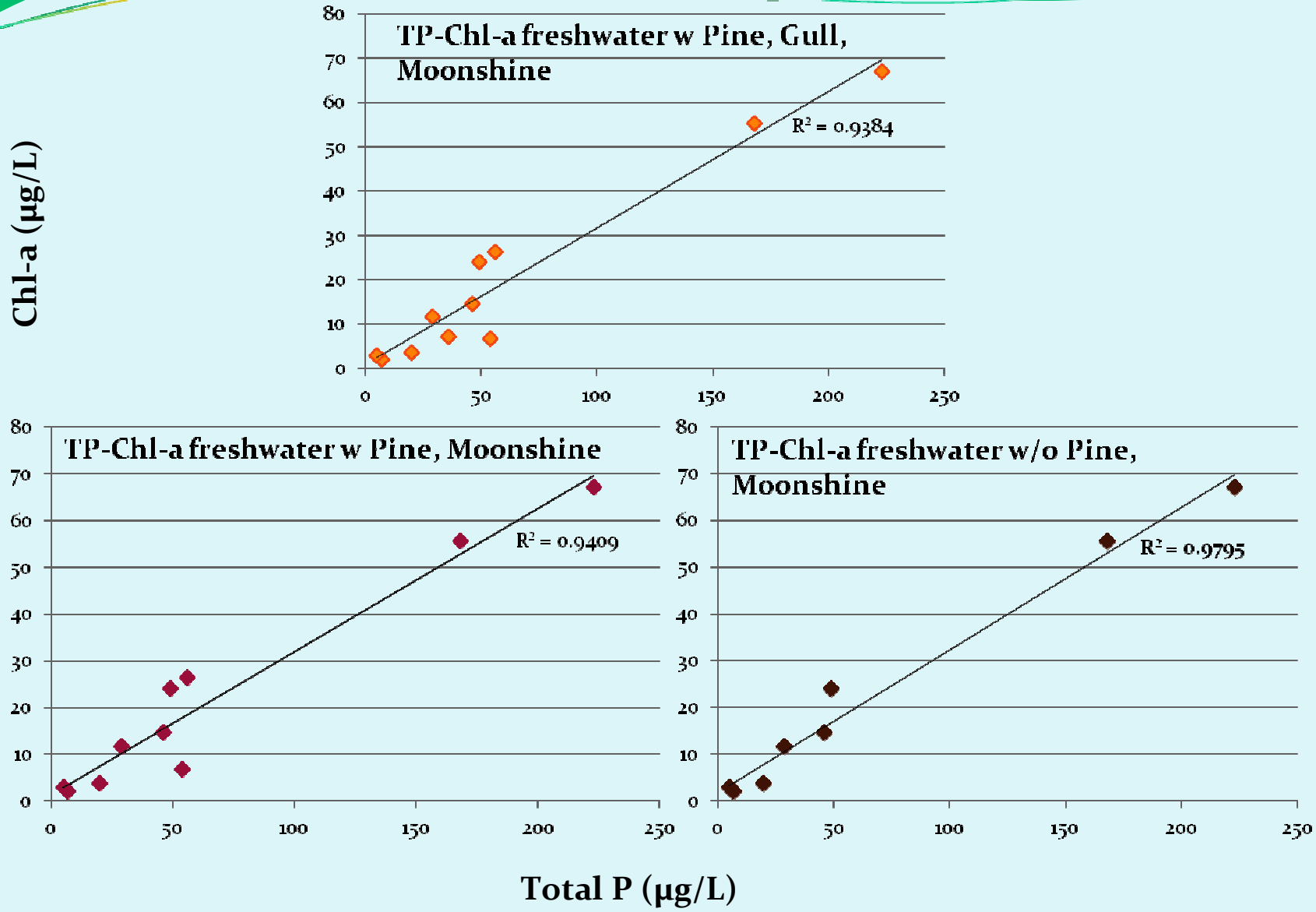
Is there a relationship between:

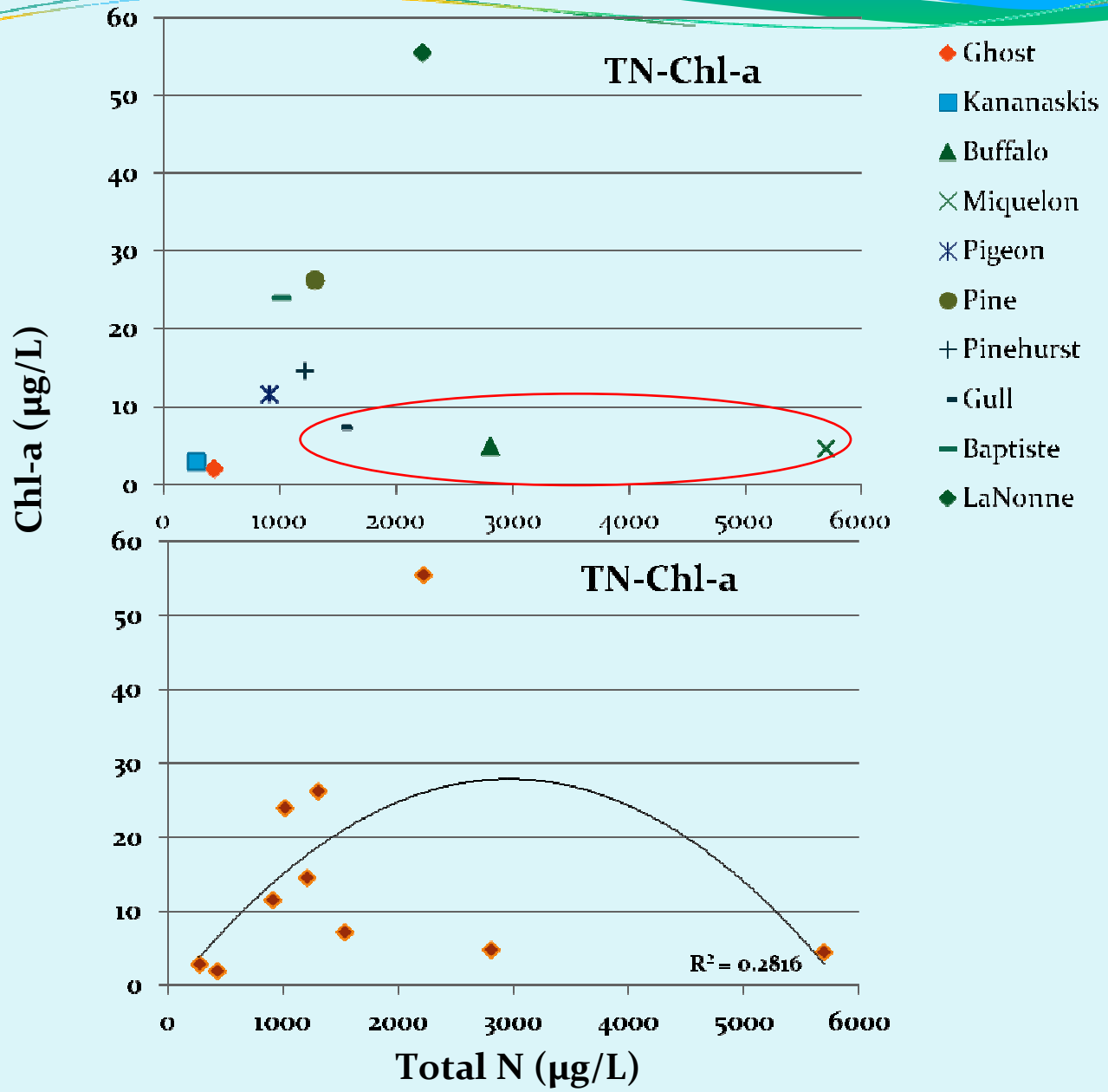
- Total P & Chlorophyll-a?
- Total N & Chlorophyll-a?
- Salinity & Chlorophyll-a?
- Salinity & Total P?
- Salinity & Total N?

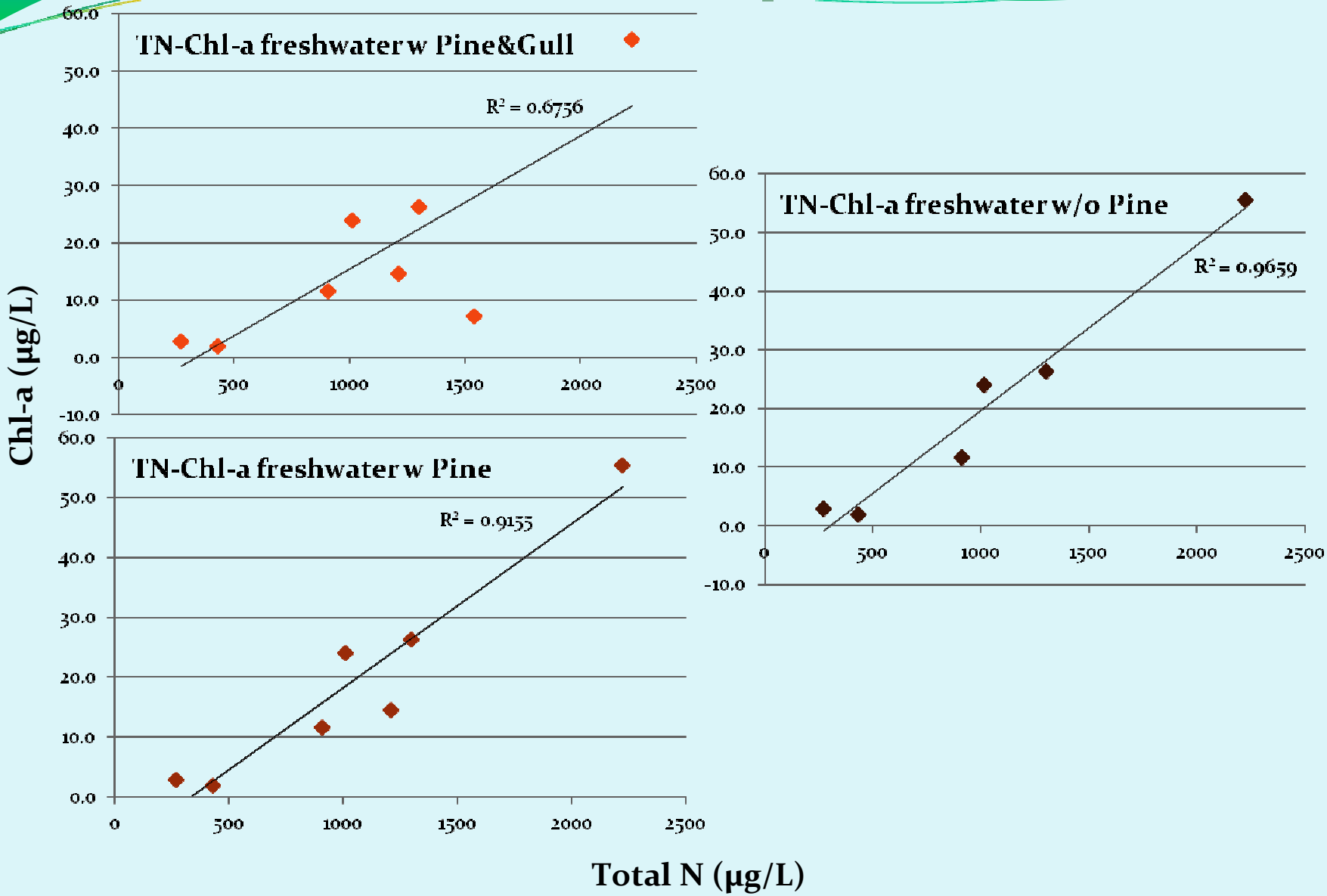
R^2 – coefficient of determination

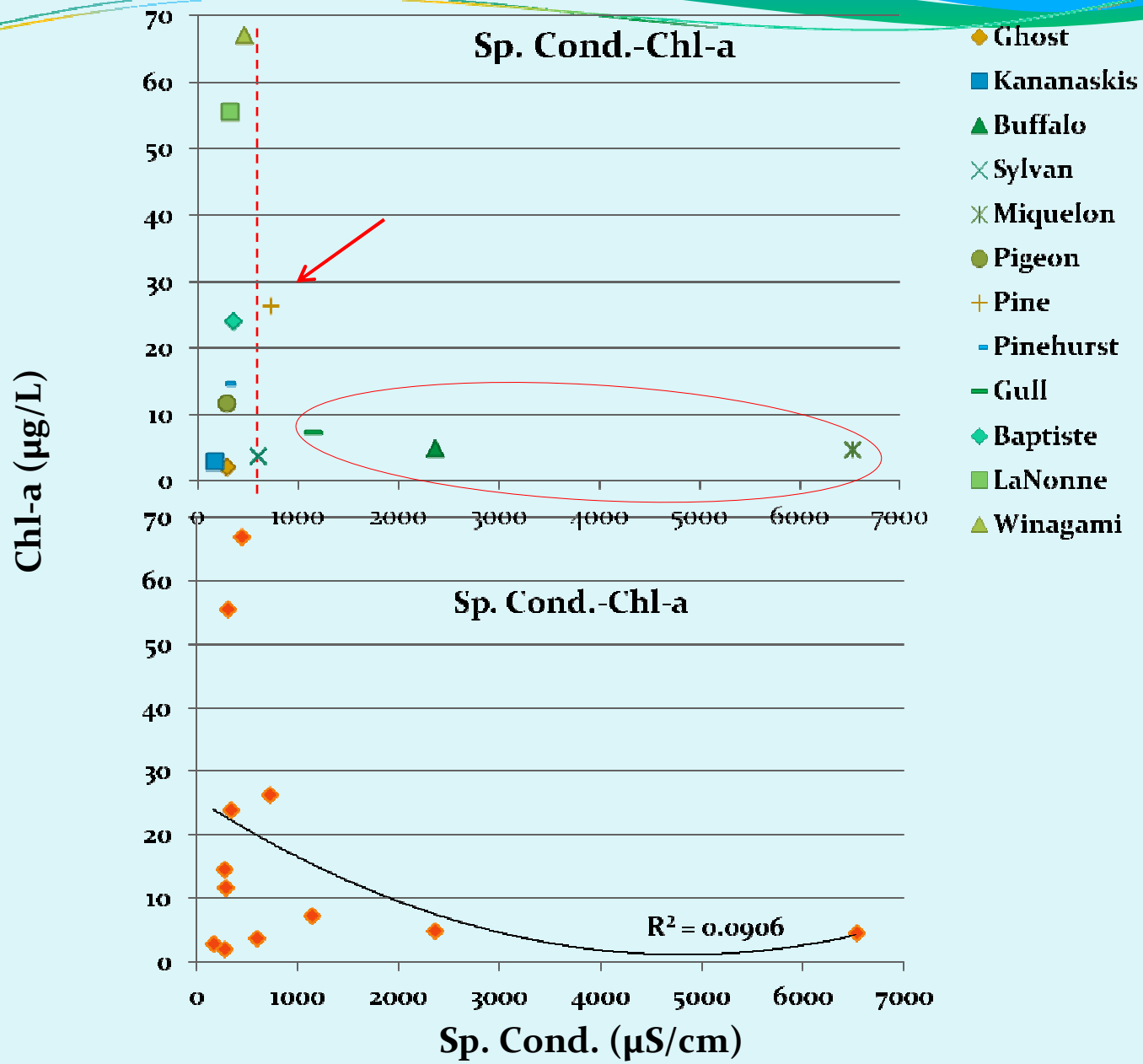
- Plot values of two variables (from table) with possible relationship on an X axis-Y axis **graph**
- **Strength of relationship** between two variables
- Value = 1 when all data points fall on the regression line (trend line)
- Value approaching 1 = stronger relationship between two variables

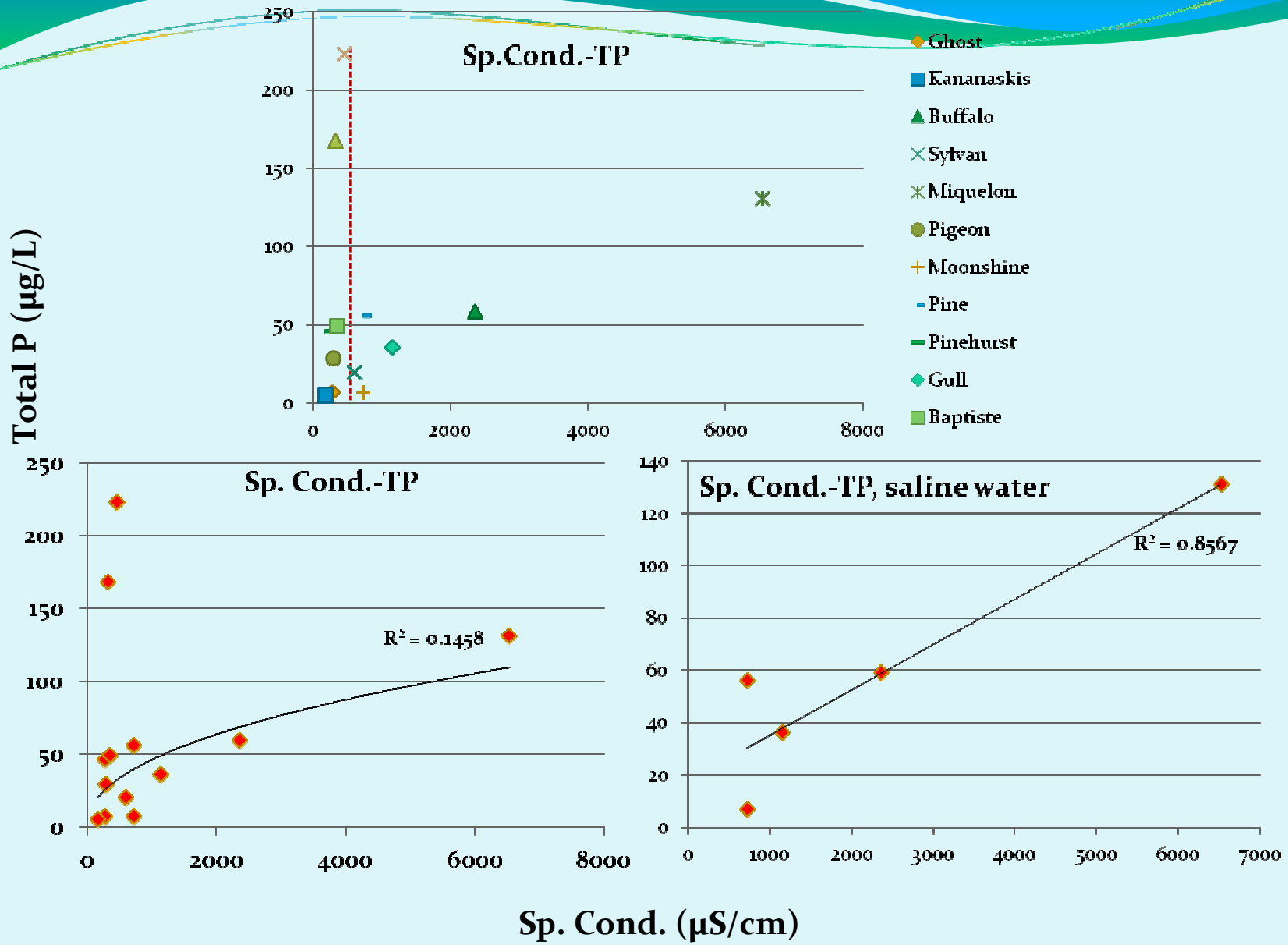

TP-Chl-a
Chl-a (µg/L)
70
60
50
40
30
20
10
0
0
50
100
150
200
250
Ghost
Kananaskis
Buffalo
Sylvan
Miquelon
Pigeon
Moonshine
Pine
Pinehurst
Gull
Baptiste
LaNonne
TP-Chl-a
R² = 0.7467
Total P (µg/L)

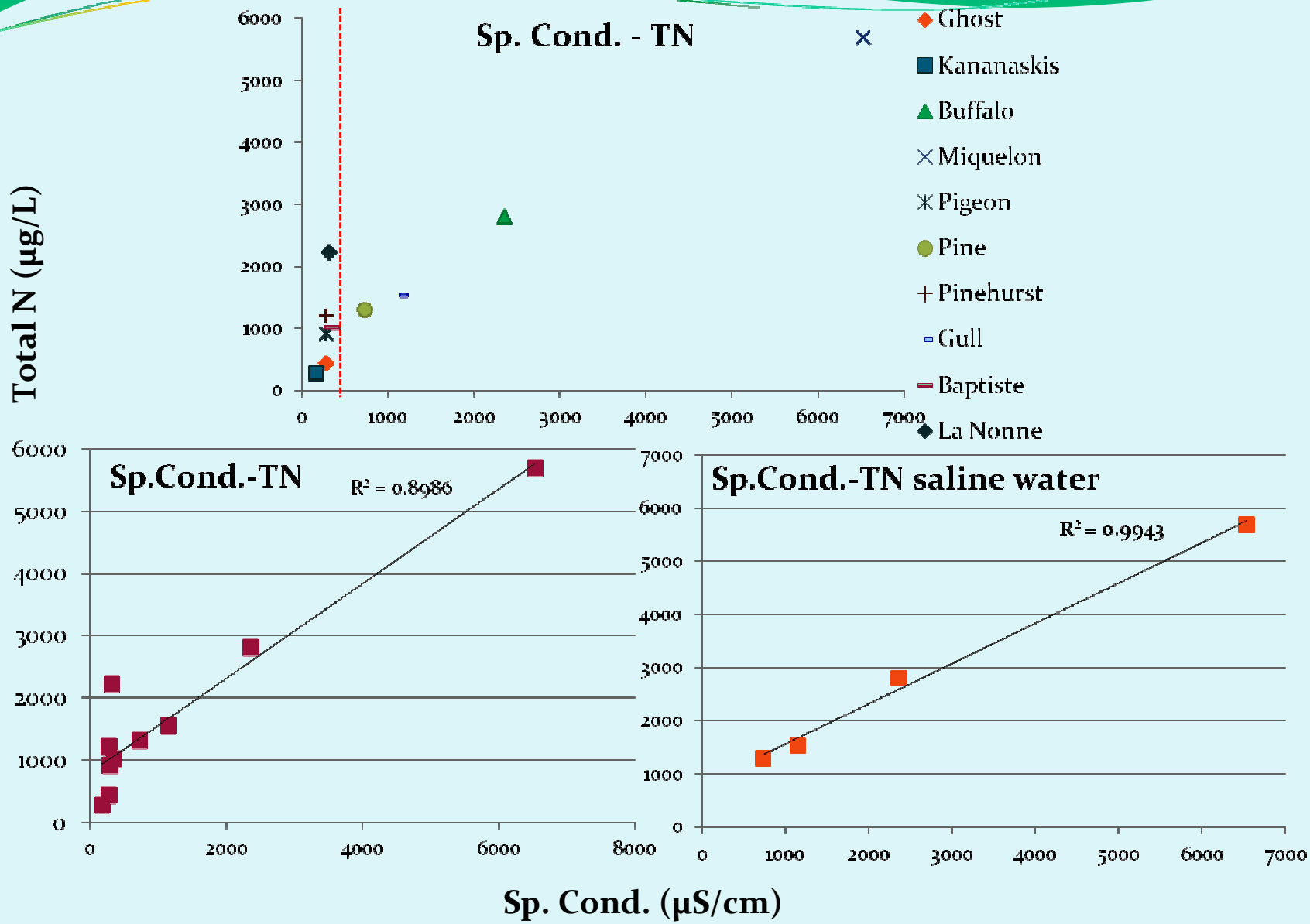

TP-Chl-a freshwater w Pine, Gull, Moonshine
R² = 0.9384
TP-Chl-a freshwater w Pine, Moonshine
R² = 0.9409
TP-Chl-a freshwater w/o Pine, Moonshine
R² = 0.9795
Chl-a (µg/L)
Total P (µg/L)
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250


TN-Chl-a
Chl-a (µg/L)
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
6000
Ghost
Kananaskis
Buffalo
Miquelon
Pigeon
Pine
Pinehurst
Gull
Baptiste
LaNonne
TN-Chl-a
R² = 0.2816
Total N (µg/L)


TN-Chl-a freshwater w Pine&Gull
R² = 0.6756
TN-Chl-a freshwater w/o Pine
R² = 0.9659
TN-Chl-a freshwater w Pine
R² = 0.9155
Chl-a (µg/L)
Total N (µg/L)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
0
500
1000
1500
2000
2500


Sp. Cond.-Chl-a
Chl-a (µg/L)
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
6000
7000
Ghost
Kananaskis
Buffalo
Sylvan
Miquelon
Pigeon
Pine
Pinehurst
Gull
Baptiste
LaNonne
Winagami
Sp. Cond.-Chl-a
R² = 0.0906
Sp. Cond. (µS/cm)


Sp.Cond.-TP
Total P (µg/L)
250
200
150
100
50
0
0
2000
4000
6000
8000
Ghost
Kananaskis
Buffalo
Sylvan
Miquelon
Pigeon
Moonshine
Pine
Pinehurst
Gull
Baptiste
Sp. Cond.-TP
R² = 0.1458
Sp. Cond.-TP, saline water
R² = 0.8567
140
120
100
80
60
40
20
0
1000
2000
3000
4000
5000
6000
7000
Sp. Cond. (µS/cm)


Sp. Cond. - TN
Total N (µg/L)
Ghost
Kananaskis
Buffalo
Miquelon
Pigeon
Pine
Pinehurst
Gull
Baptiste
La Nonne
Sp.Cond.-TN
R² = 0.8986
Sp.Cond.-TN saline water
R² = 0.9943
Sp. Cond. (µS/cm)

Conclusions

- In slightly alkaline freshwaters, TN and TP each have a significant linear relationship with Chl-*a;* need to find out interaction of TN & TP
- The effect of salinity to decrease Chl-*a* begins at TDS ~450 mg/L or ~700 µS/cm specific conductivity; may need to change freshwater boundary value
- Salinity tends to retain both TP & TN (more) – excessive amounts (> freshwaters) can lead eutrophication at low salinity levels ~700 - ~1000 µS/cm
- At >1000 µS/cm Chl-*a* declines despite high TN and TP concentrations
- Need to know corresponding algal communities – freshwater & range of salinity levels.

Conclusion

- The management of nutrients in slightly alkaline lakes need to consider:
  - both N and P concentrations &
  - lake salinity status especially very slight salinity of ~700 to <1000 µS/cm specific conductivity
- [Note: cyanobacteria (not an algae) can fix N from the air]

THANK YOU

Contact

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