Analysis of Nutrient-Response Characteristics to Support Criteria Development for Constructed Reservoirs

Meredith Pavlick
Tamim Younos
Carl Zipper

Virginia Tech and Virginia Water Resources Research Center

National Water Monitoring Conference - May 20, 2008 - Atlantic City, NJ

Outline

- Region 3 nutrient criteria development
- Reservoir nutrient criteria
- Project objectives
  - Reservoir database development
  - Reservoir data analysis and results
- Conclusions

Nutrient Criteria Development

- 1998 EPA mandate for numeric nutrient criteria nationwide
- Nitrogen, phosphorus, chlorophyll-a, secchi depth (nutrients and responses)
- Rivers, streams, lakes, reservoirs, wetlands, estuaries

Nutrient Criteria Development

- All Region 3 states scheduled to complete criteria by 2010
- All in different phases of development
- Some criteria are awaiting final EPA approval

Reservoir Criteria

- Major challenge – **reservoirs**
- Why?
  - Limited data
  - Application of lake-based nutrient relationships

Characteristic dendritic shape of reservoirs

Characteristic rounded shape of natural lakes

Source: http://www.unep.or.jp/ietc/publications/short_series/lakereservoirs-2/IMG/fig06Reservoirs_Lakes.gif

Project Objectives

- Develop a regional reservoir dataset
- Determine if reservoirs demonstrate consistent relationships between nutrient levels and response variables
- Determine if physical features and ecoregion exert a consistent and predictable influence on reservoirs' nutrient-response characteristics.

Database Development

- Data obtained from DE, MD, PA, VA, WV

- Challenges
  - Limited information
  - Inconsistent formats
  - Unverified collection methods (physical)
  - Post-9/11 restrictions (physical)

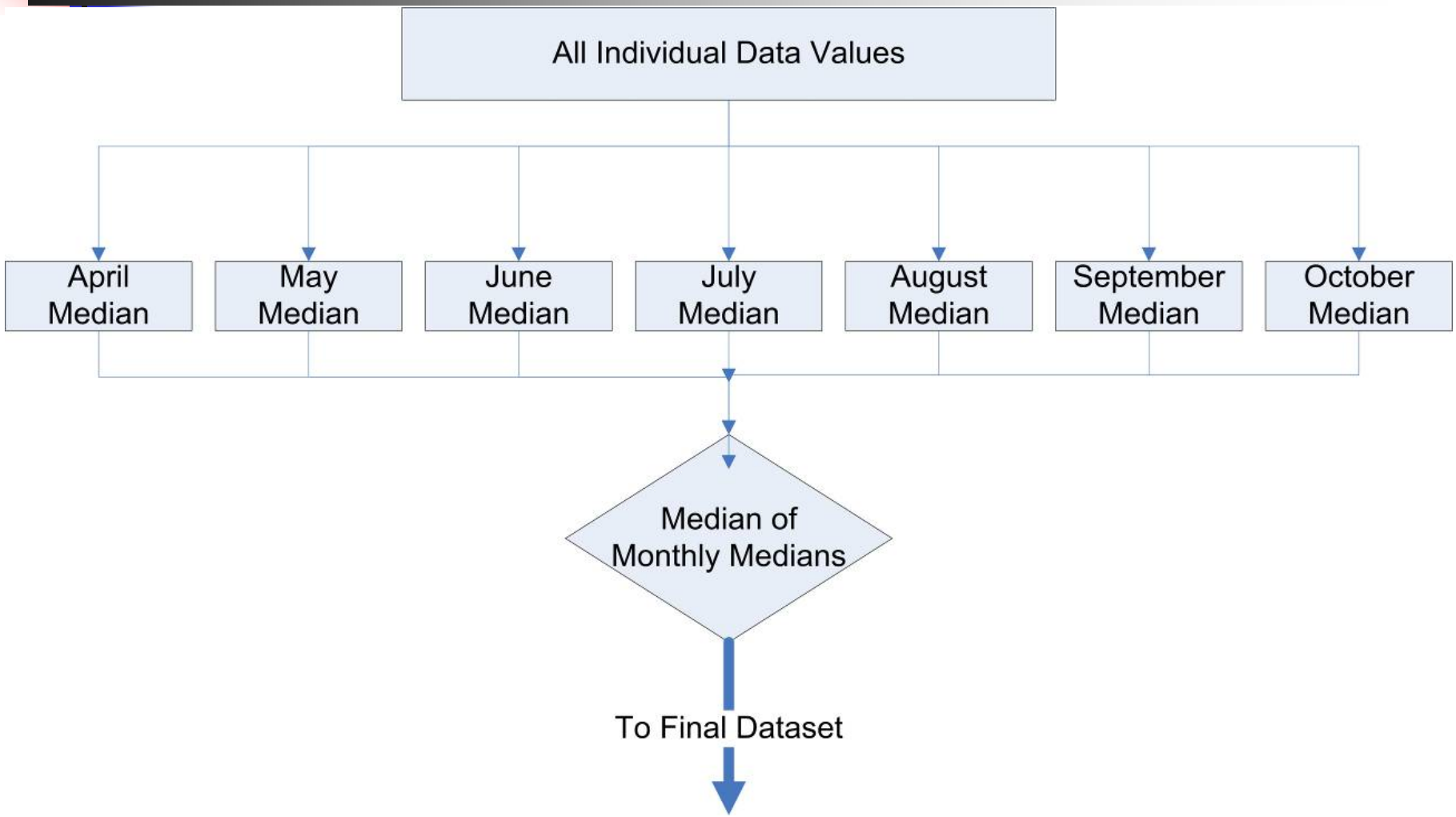
Database Development

- Water quality data
  - TP, TN, chlorophyll-a, secchi depth
- Physical characteristics
  - Depth, volume, surface area, retention time

Database Development

- Water Quality Data
  - 1 to over 1000 monitoring points for a given reservoir
  - Data reduction process to equally weigh reservoirs
  - Data from April to October included - 3 months minimum, 1990 to present

Database Development



Database Development

	MD				PA				VA				WV			
	SD	TN	TP	Chl-a	SD	TN	TP	Chl-a	SD	TN	TP	Chl-a	SD	TN	TP	Chl-a
	ft	*mg/l*	*mg/l*	*µg/l*	*ft*	*mg/l*	*mg/l*	*µg/l*	*ft*	*mg/l*	*mg/l*	*µg/l*	*ft*	*mg/l*	*mg/l*	*µg/l*
Count	**21**	**13**	**21**	**22**	**74**	**96**	**92**	**90**	**66**	**70**	**70**	**71**	**24**	**0**	**19**	**20**
Max	5.0	3.8	0.153	92.6	5.6	4.4	0.196	160	7.9	1.7	0.155	180	6.5	0	0.072	43.7
Min	0.4	0.3	0.008	1.85	0.3	0.1	0.005	1.35	0.4	0.2	0.010	1.34	0.3	0	0.004	0.50

Database Development

- Physical Characteristics
  - Multiple values for same characteristic
    - Average, maximum, unknown
  - Data reduction process
    - Average values
    - Multiple values averaged- one value per reservoir

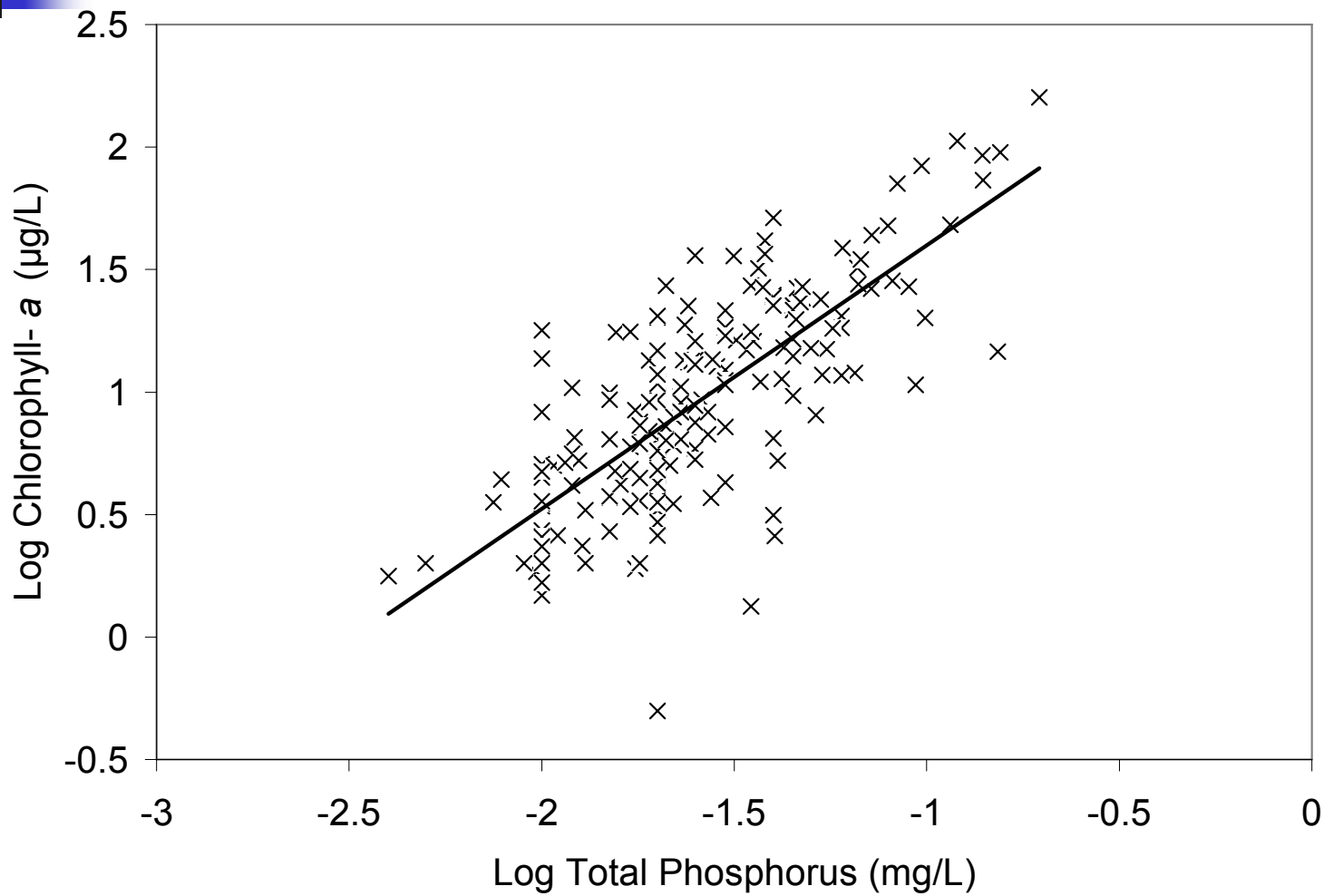
Database Development

	MD				PA				VA				WV			
	Surface Area	Depth	Volume (x1000)	Retention Time	Surface Area	Depth	Volume (x1000)	Retention Time	Surface Area	Depth	Volume (x1000)	Retention Time	Surface Area	Depth	Volume (x1000)	Retention Time
	ac	*ft*	*ac-ft*	*days*	*ac*	*ft*	*ac-ft*	*days*	*ac*	*ft*	*ac-ft*	*days*	*ac*	*ft*	*ac-ft*	*days*
Count	22	22	22	0	96	37	32	84	68	68	69	11	25	15	24	23
Max	4,500	151	132	NA	5,740	125	110	660	48,968	97	1,648	1,222	2,745	16	192	405
Min	5	3	15	NA	2	1	15	1	6	3	41	16	1	4	5	2

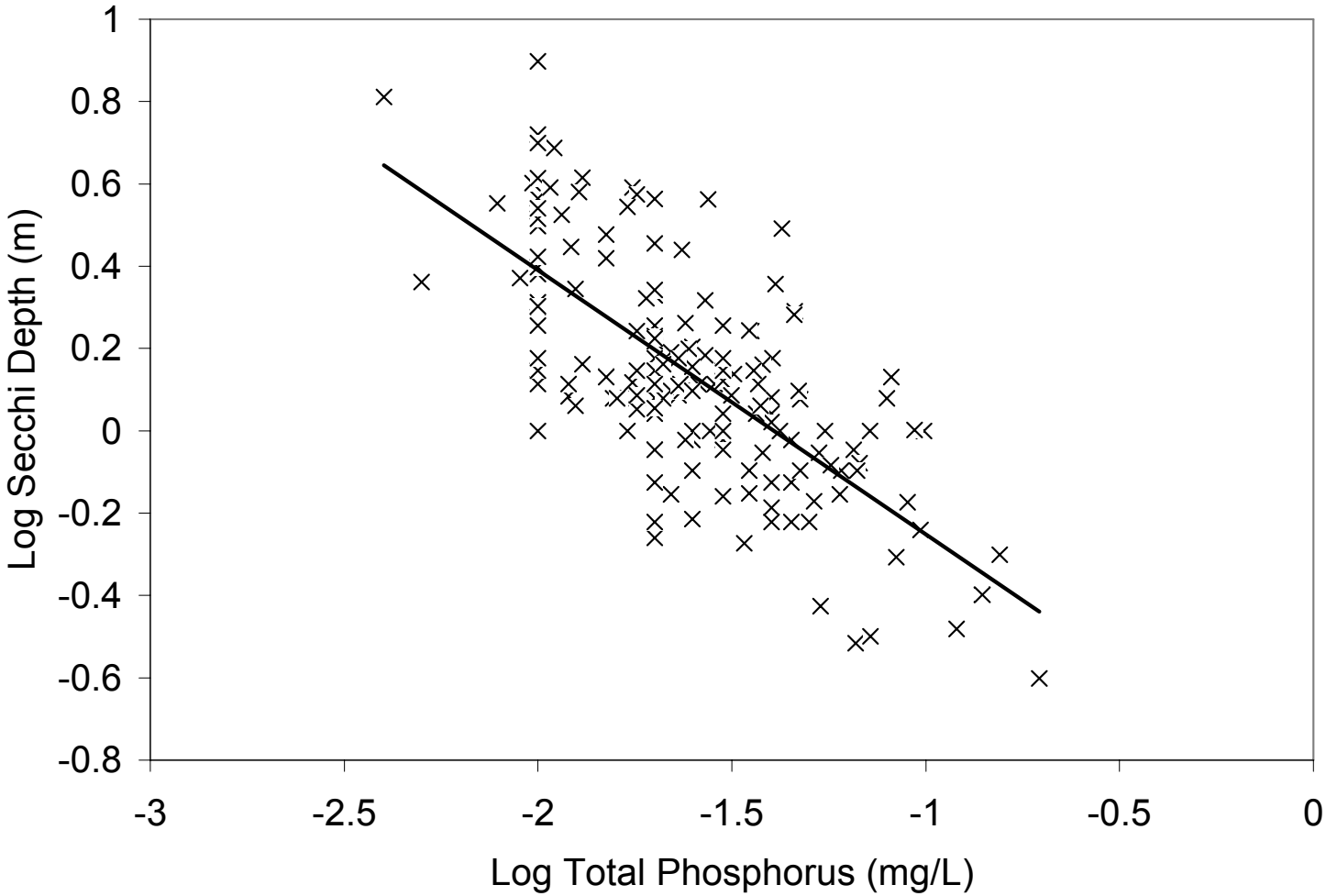
Data Analysis

- Linear Regression Models
  - Nutrient vs. response variables
- Multiple Regression
  - Nutrients, physical characteristics, nutrient responses
- Ecoregion Analysis
  - Linear and multiple regression

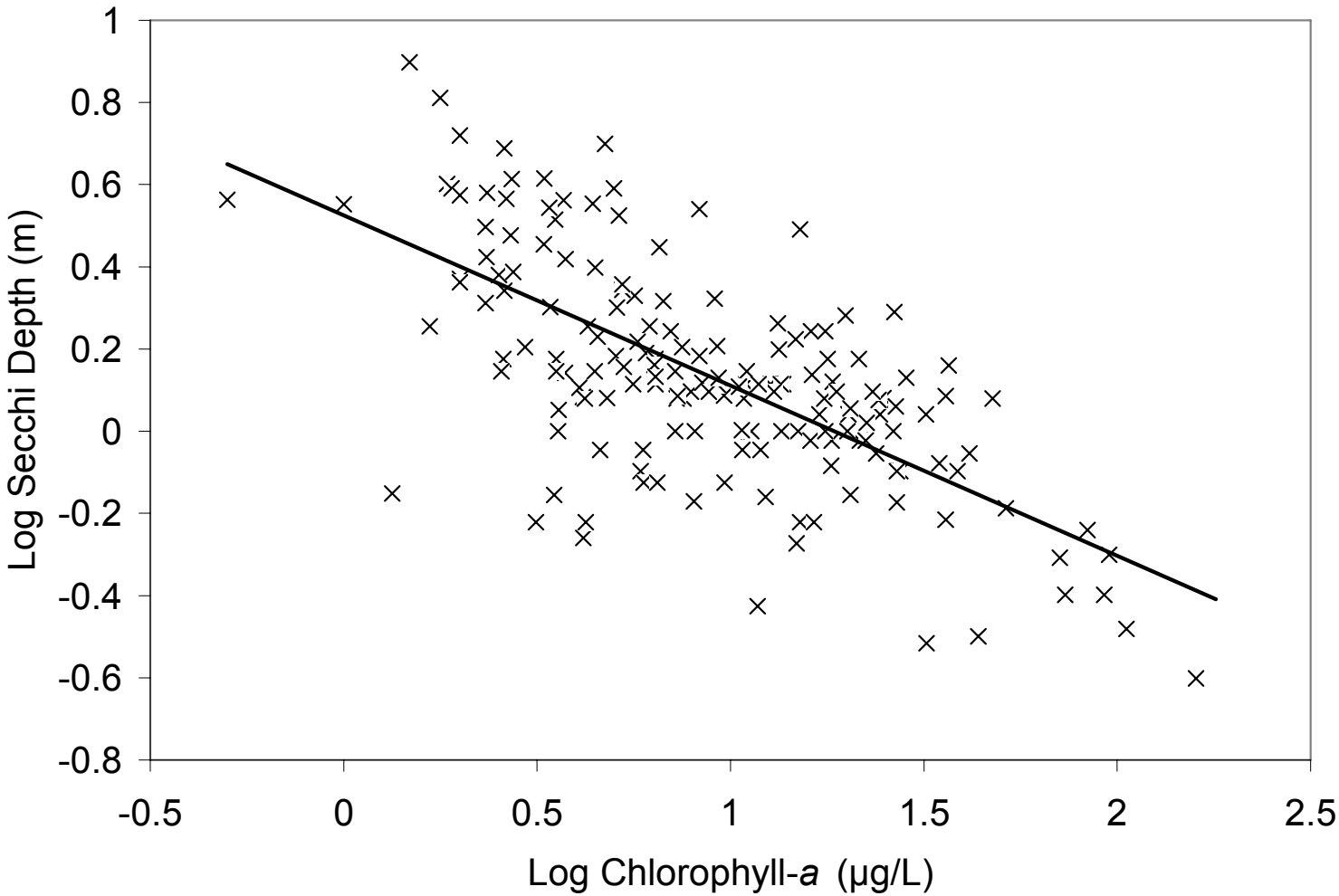
Data Analysis – Linear Models



Data Analysis – Linear Models



Data Analysis – Linear Models



Data Analysis – Linear Models

Independent Variable	Dependent Variable	n	Model Equation	R^2	p
TP (mg/L)	Chlorophyll-a (µg/L)	193	y = 1.0756x + 2.6743	0.58	<0.0001
TP (mg/L)	Secchi depth (m)	175	y = -0.6414x - 0.8931	0.50	<0.0001
TN (mg/L)	Secchi depth (m)	150	y = -0.5328x - 0.1217	0.23	<0.0001
TN (mg/L)	Chlorophyll-a (µg/L)	171	y = 0.783x + 1.0807	0.31	<0.0001
Chlorophyll-a (µg/L)	Secchi depth (m)	174	y = -0.4144x + 0.5255	0.46	<0.0001

Multiple Regression Models

Independent variables		Dependent variable	n	R^2	p
x1	TP (mg/l)	Secchi Depth (m)			<0.0001
x2	Surface Area (ac)		169	0.48	0.4707
x1	**TP (mg/l)**	**Secchi Depth (m)**			**<0.0001**
x2	**Depth (ft)**		**124**	**0.53**	**<0.0001**
x1	TP (mg/l)	Secchi Depth (m)			<0.0001
x2	Volume (ac ft)		125	0.50	0.0964
x1	**TP (mg/l)**	**Secchi Depth (m)**			**<0.0001**
x2	**Retention Time (d)**		**85**	**0.52**	**0.0027**
x1	TN (mg/l)	Secchi Depth (m)			<0.0001
x2	Surface Area (ac)		145	0.20	0.8992
x1	**TN (mg/l)**	**Secchi Depth (m)**			**0.0004**
x2	**Depth (ft)**		**103**	**0.36**	**<0.0001**
x1	**TN (mg/l)**	**Secchi Depth (m)**			**0.0007**
x2	**Volume (ac ft)**		**101**	**0.20**	**0.0036**
x1	TN (mg/l)	Secchi Depth (m)			<0.0001
x2	Retention Time (d)		69	0.33	0.0773

Multiple Regression Models

Independent variables		Dependent variable	n	R^2	p
x1	TP (mg/l)	Chl-*a* (µg/l)			<0.0001
x2	Surface Area (ac)		186	0.56	0.9885
x1	TP (mg/l)	Chl-*a* (µg/l)			<0.0001
x2	Depth (ft)		133	0.49	0.5520
x1	TP (mg/l)	Chl-*a* (µg/l)			<0.0001
x2	Volume (ac ft)		131	0.50	0.5495
x1	TP (mg/l)	Chl-*a* (µg/l)			<0.0001
x2	Retention Time (d)		97	0.56	0.8232
x1	TN (mg/l)	Chl-*a* (µg/l)	165	0.31	<0.0001
x2	Surface Area (ac)				0.2722
x1	**TN (mg/l)**	**Chl-*a* (µg/l)**			**<0.0001**
x2	**Depth (ft)**		**112**	**0.3**	**0.0200**
x1	TN (mg/l)	Chl-*a* (µg/l)			<0.0001
x2	Volume (ac ft)		107	0.28	0.1260
x1	TN (mg/l)	Chl-*a* (µg/l)			<0.0001
x2	Retention Time (d)		84	0.29	0.3774

Physical Linear Regression Models

Independent Variable	Dependent Variable	n	Model Equation	R^2	p
Depth (m)	Secchi depth (m)	128	y = 0.352x - 0.2573	0.32	<0.0001
Volume (ac-ft)	Secchi depth (m)	135	y = 0.0953x - 0.1739	0.15	<0.0001
Retention Time (d)	Secchi depth (m)	94	y = 0.1729x - 0.0874	0.13	0.0004
Depth (m)	Chlorophyll-a (µg/l)	135	y = -0.3523x + 1.3191	0.13	<0.0001

Ecoregion Influences

Ecoregion 9 Influences

Independent Variable	Dependent Variable	n	Model Equation	R^2	p
TP (mg/L)	Chlorophyll-a (µg/L)	59	y = 0.9959x + 2.5305	0.43	<0.0001
TP (mg/L)	Secchi depth (m)	56	y = -0.5837x - 0.8517	0.41	<0.0001
TN (mg/L)	Secchi depth (m)	52	y = -0.0141x + 0.0772	0.0002	0.9159
TN (mg/L)	Chlorophyll-a (µg/L)	55	y = 0.6944x + 1.0355	0.20	0.0007
Chlorophyll-a (µg/L)	Secchi depth (m)	56	y = -0.3161x + 0.3772	0.27	<0.0001

Ecoregion 11 Influences

Independent Variable	Dependent Variable	n	Model Equation	R^2	p
TP (mg/L)	Chlorophyll-a (µg/L)	49	y = 1.2491x + 2.9232	0.55	<0.0001
TP (mg/L)	Secchi depth (m)	46	y = -0.9866x - 1.4655	0.62	<0.0001
TN (mg/L)	Secchi depth (m)	27	y = -0.6761x + 0.0445	0.39	0.0005
TN (mg/L)	Chlorophyll-a (µg/L)	32	y = 0.7009x + 0.9096	0.34	0.0004
Chlorophyll-a (µg/L)	Secchi depth (m)	49	y = -0.5263x + 0.6291	0.55	<0.0001

Conclusions

- Analysis supports literature findings: reservoirs are somewhat unpredictable with regard to nutrient responses
- TP is moderately to strongly correlated with secchi depth and chlorophyll-*a*
- TN is weakly correlated with response variables
- Secchi depth may not be strongly influenced by chlorophyll-*a*
- Physical characteristics and ecoregions do not have a strong influence on nutrient responses

Recommendations

- Develop regional data reporting and storage methods
- Develop robust and reliable physical characteristic dataset – explore relationships
- Determine other factors influencing secchi depth measurements

Special to USEPA Region 3 for funding this project.

Report online:

http://www.vwrrc.vt.edu/special_reports.html#2008