Golden Alga (*Prymnesium parvum*) – An Emerging Threat

Reynaldo Patino, Unit Leader and Professor

U.S. Geological Survey, Texas Coop. Fish & Wildlife Research Unit
Texas Tech University
Lubbock

Reynaldo.patino@ttu.edu

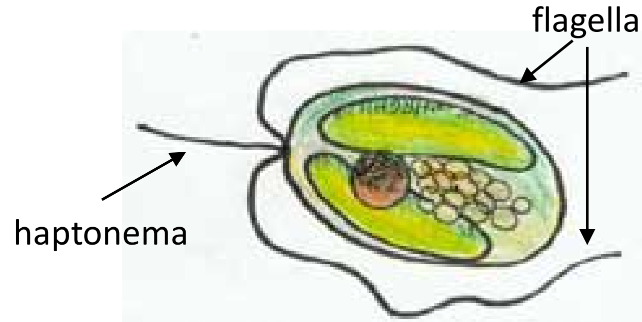
* Interpretation of unpublished data contained in this presentation is still ongoing and should not be cited.

Outline

- Biology
- Distribution
- Ecological Impacts
- Origin (is it an invasive species?) and Water Quality Requirements
- Monitoring Options
- Treatment Options

Biology

- Single-celled species
- Paired flagella, for motility
- Short haptonema, possibly for attachment or food acquisition
- Gain nutrition by "mixotrophy"
  - Photosynthesis + uptake of dissolved and particulate organic material
- Tolerate wide range of salinity
  - Minimum for blooms (0.5-1 psu, ≈ 2000 µS/cm)
- Water takes golden coloration during blooms, foam forms along shoreline
- In North America, toxic blooms typically occur during cooler months of the year



Golden Alga, *Prymnesium parvum*
Drawing by Robert G. Howells, TPWD

Picture credit: Greg Southard, TPWD

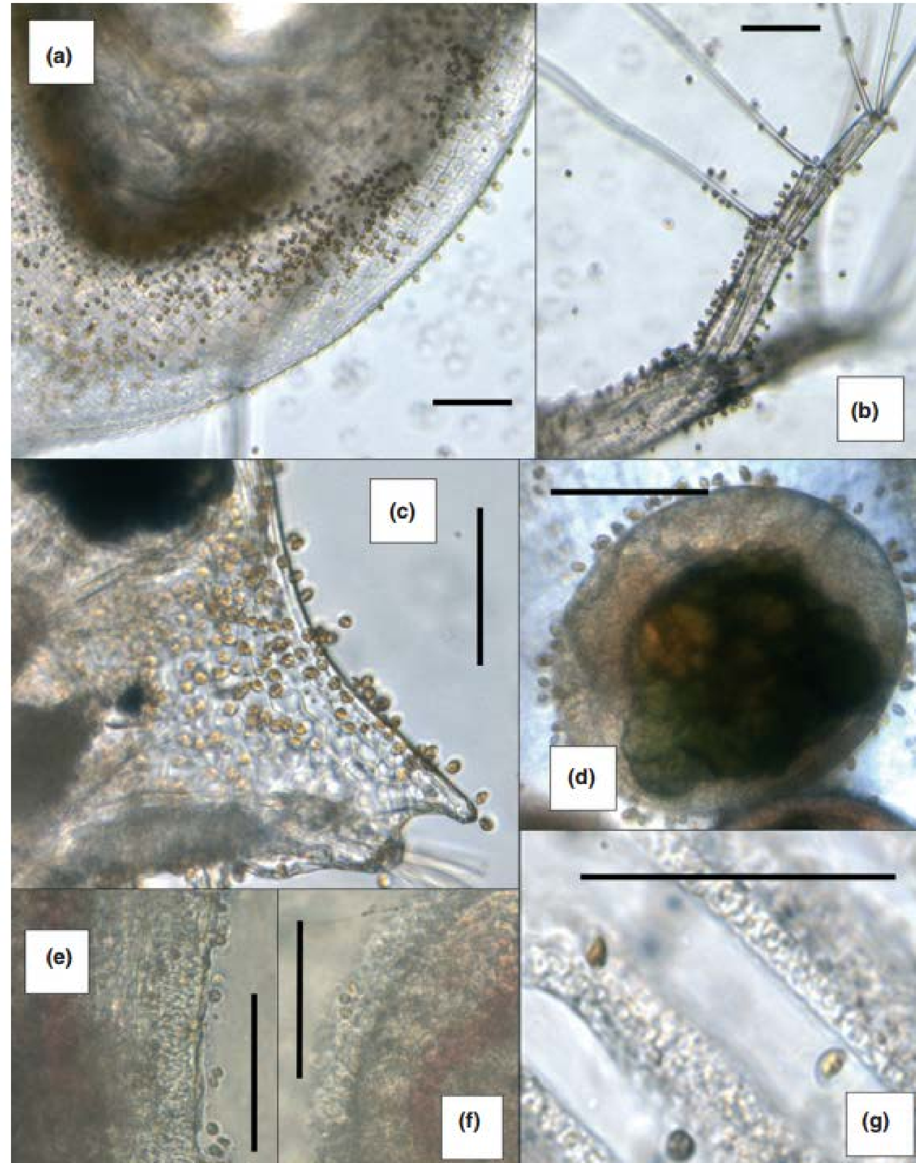
Golden Alga

Picture credits: TPWD

Shoreline Foam

Biology

- Multiple toxins
- Believed to affect mostly aquatic gilled organisms (fishes, some invertebrates)
- Toxins target surface of gills (and skin), and death may occur due to respiratory and osmoregulatory failure
- One study suggested that direct contact with body surfaces is necessary for toxicity (Remmel and Hambright, 2012)

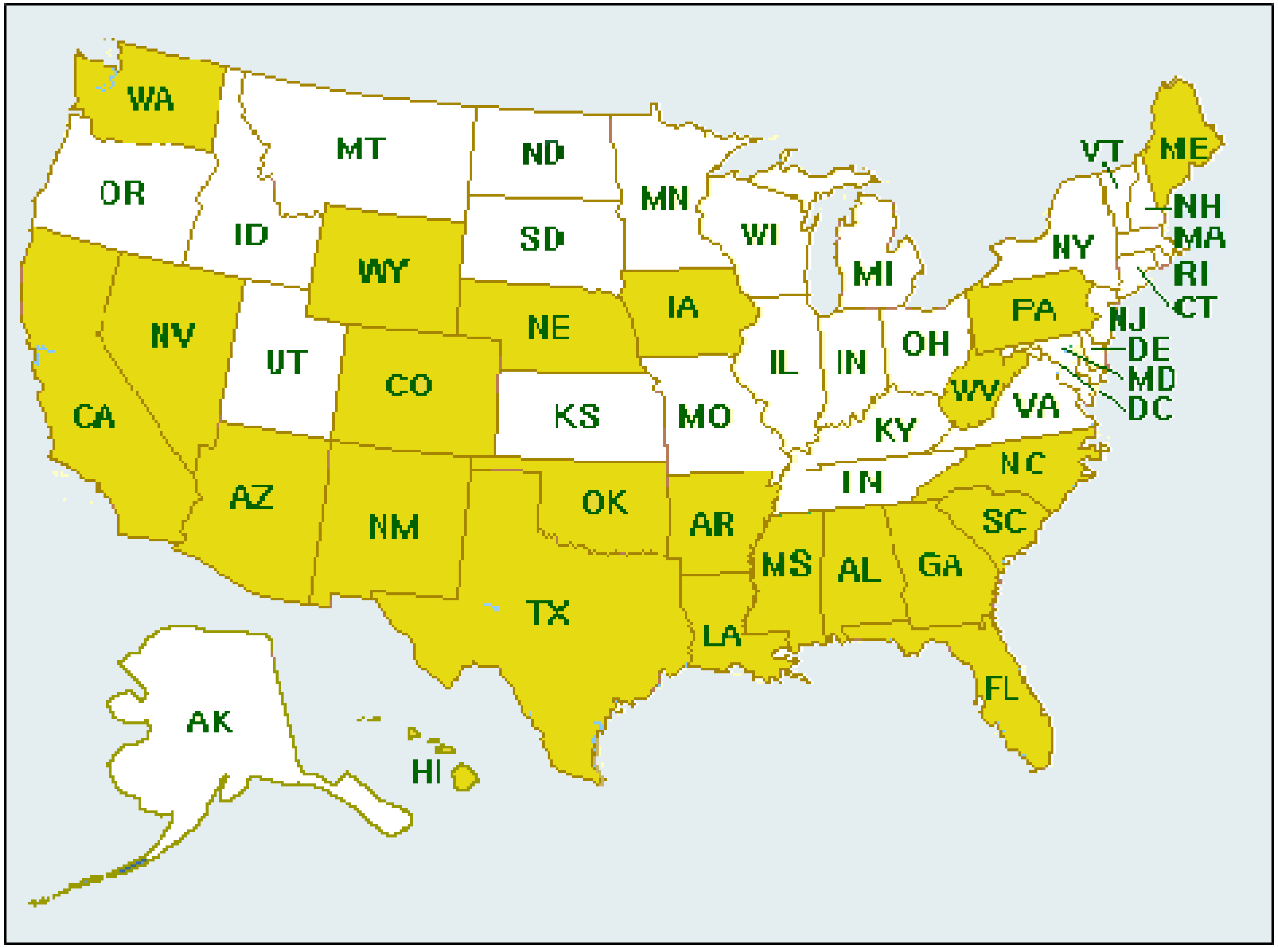


Remmel and Hambright (2012)

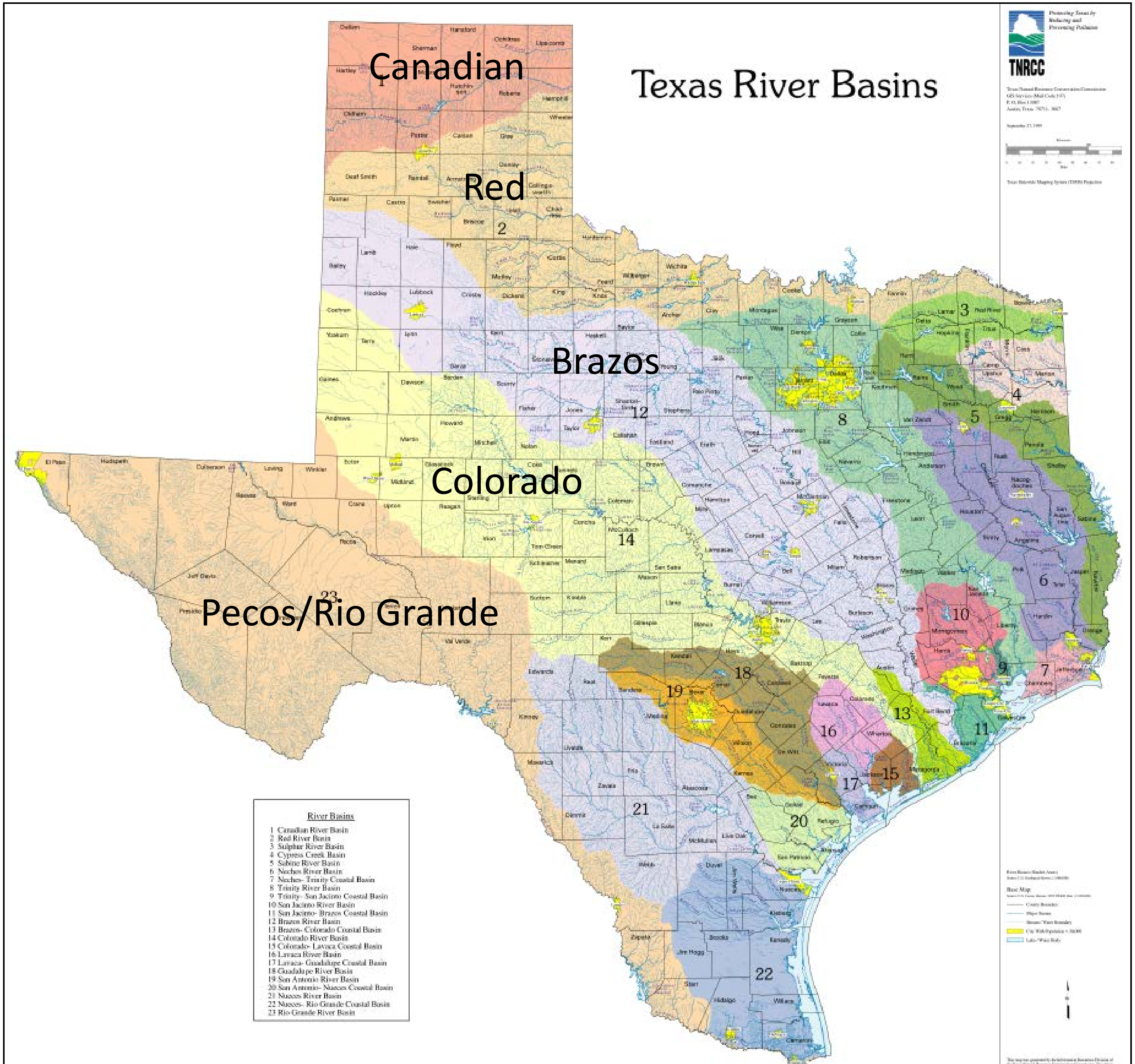
Distribution

- Originally coastal/estuarine species
- Reported in every major continent except Antarctica
- Reported also in inland waters,
  - Middle East: fish ponds
  - China: saline lakes
  - United States: saline reservoirs and streams (> 0.5-1 psu)
- First confirmed fish kill in Netherlands, 1920s
- In North America, first confirmed toxic bloom in Pecos River, Texas, 1985
- Now reported in at least 23 U.S. states

States in the U.S. reporting golden alga



Israël, N.M.D., 2013. Surface water quality in the Pecos River basin: associations with golden alga presence and unplugged oil/gas well densities. A Thesis in Wildlife, Aquatic, and Wildlands Science and Management, Texas Tech University, Lubbock, Texas, USA


Texas River Basins
TNRCC
Canadian
Red
Brazos
Colorado
Pecos/Rio Grande
River Basins
1 Canadian River Basin
2 Red River Basin
3 Sulphur River Basin
4 Cypress Creek Basin
5 Sabine River Basin
6 Neches River Basin
7 Neches- Trinity Coastal Basin
8 Trinity River Basin
9 Trinity- San Jacinto Coastal Basin
10 San Jacinto River Basin
11 San Jacinto- Brazos Coastal Basin
12 Brazos River Basin
13 Brazos- Colorado Coastal Basin
14 Colorado River Basin
15 Colorado- Lavaca Coastal Basin
16 Lavaca River Basin
17 Lavaca- Guadalupe Coastal Basin
18 Guadalupe River Basin
19 San Antonio River Basin
20 San Antonio- Nueces Coastal Basin
21 Nueces River Basin
22 Nueces- Rio Grande Coastal Basin
23 Rio Grande River Basin

Ecological Impacts: General

- Considered one of the most harmful algal species to fish
- As of 2008, estimated loss of nearly 35 million fish in Texas alone (Southard et al., 2010)


Picture credits: Gary Turner, BRA


Picture credit: TPWD

Ecological Impacts: Fish Populations

	Upper Colorado River						Brazos River					
	CPUE[a]		PSD (%)		PSD-P (%)		CPUE[a]		PSD (%)		PSD-P (%)	
Species	Net effect	q-value	Net effect	q-value	Net effect	q-value	Net effect	q-value	Net effect	q-value	Net effect	q-value
Channel catfish	-1.2	**0.02**	-36	**0.04**	-15	**0.05**	4.7	*0.05*[b]	12	0.12	2	0.12
Flathead catfish	-0.2	**0.04**	-78	**0.04**	-39	0.14	0.0	0.17	3	0.2	1	0.20
Blue catfish	0.1[c]	**0.04**	-75	**0.05**	-35	0.06	-3.2	**0.04**	-7	0.14	-2	0.07
Largemouth bass	-9.5	**0.05**	-39	**0.04**	-18	**0.04**	-39.9	0.17	-9	0.16	-3	0.16
Bluegill	-47.0	**0.04**	-29	**0.04**	0	0.14	-89.4	0.14	6	0.16	-1	0.13
White bass	-7.8	**0.04**	-67	**0.04**	-50	**0.05**	1.7	0.11	8	0.14	1	0.16
White crappie	-4.8	0.08	-62	**0.04**	-47	**0.05**	-0.7	0.17	-17	0.11	-5	0.16
Gizzard shad	64.8	0.11					146.6	0.06				
River carpsucker	-5.2	**0.04**										
Freshwater drum	-3.2	**0.05**										
Common carp	-3.1	0.06										
Longnose gar	-6.5	0.07										

CPUE = catch per unit effort (relative abundance)
PSD = proportional size distribution
PSD-P = proportional size distribution of preferred-size fish

- Ecological damage is far greater in Colorado than Brazos reservoirs
- Difference may be related to bloom frequency and dynamics: more regular and of longer duration in Colorado than Brazos reservoirs.

VanLandeghem, M.M., Farooqi, M., Farquhar, B., Patiño, R. 2013. Impacts of golden alga Prymnesium parvum on fish populations in reservoirs of the Upper Colorado River and Brazos River basins, Texas. Transactions of the American Fisheries Society 142: 581-595.

Ecological Impacts: “Non-gilled” Organisms

- There are reports of aquatic turtle and birds kills associated with golden alga blooms
- These effects are likely indirect, via secondary blooms of pathogenic microbes growing off fish carcasses

Spiny Softshell

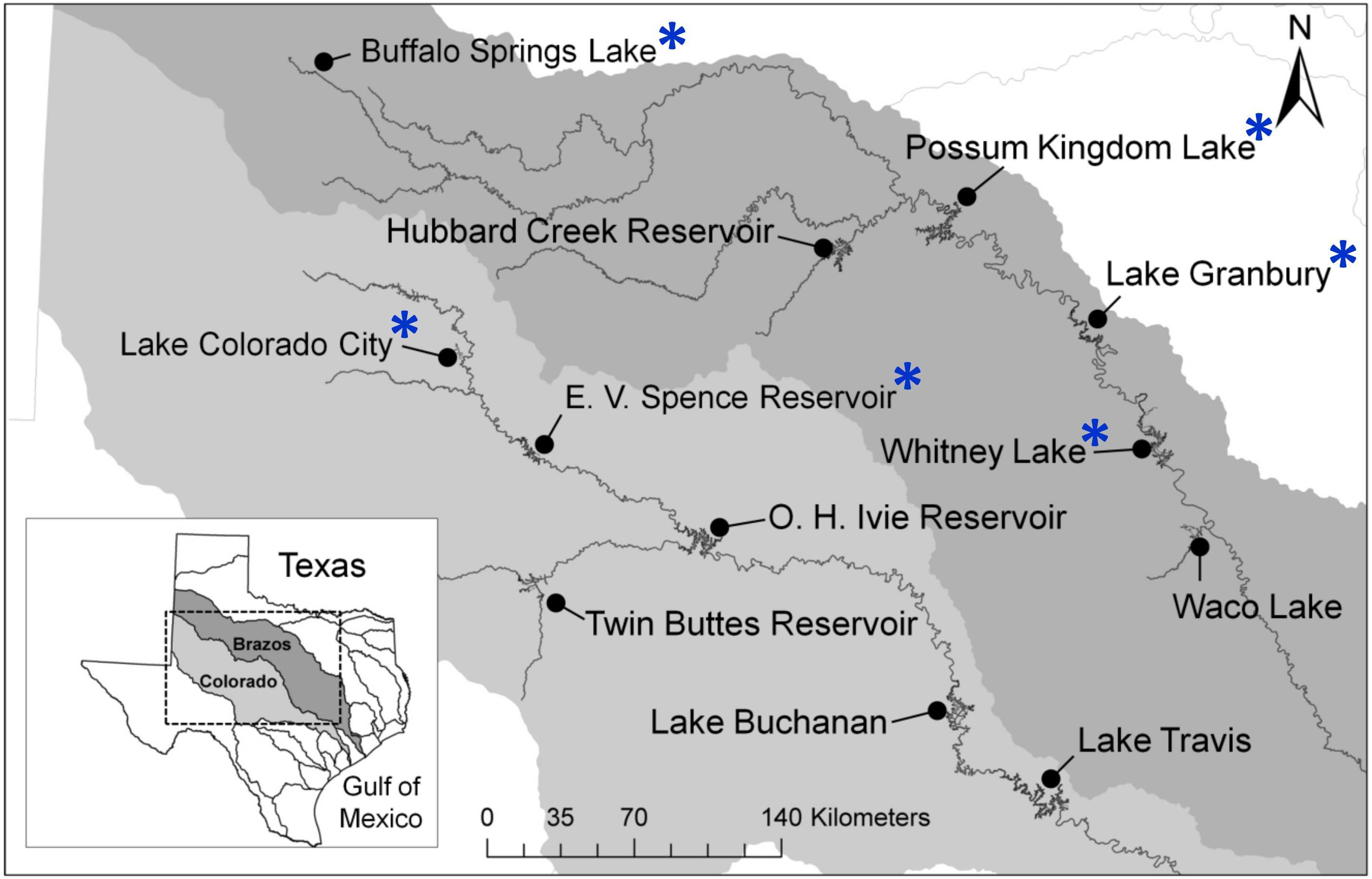
Red-eared Slider

Photographs of dead aquatic turtles found near shoreline during golden alga bloom in Ransom Canyon Lake, Texas, April 2014 (unpublished data)

Origin and Water Quality Requirements

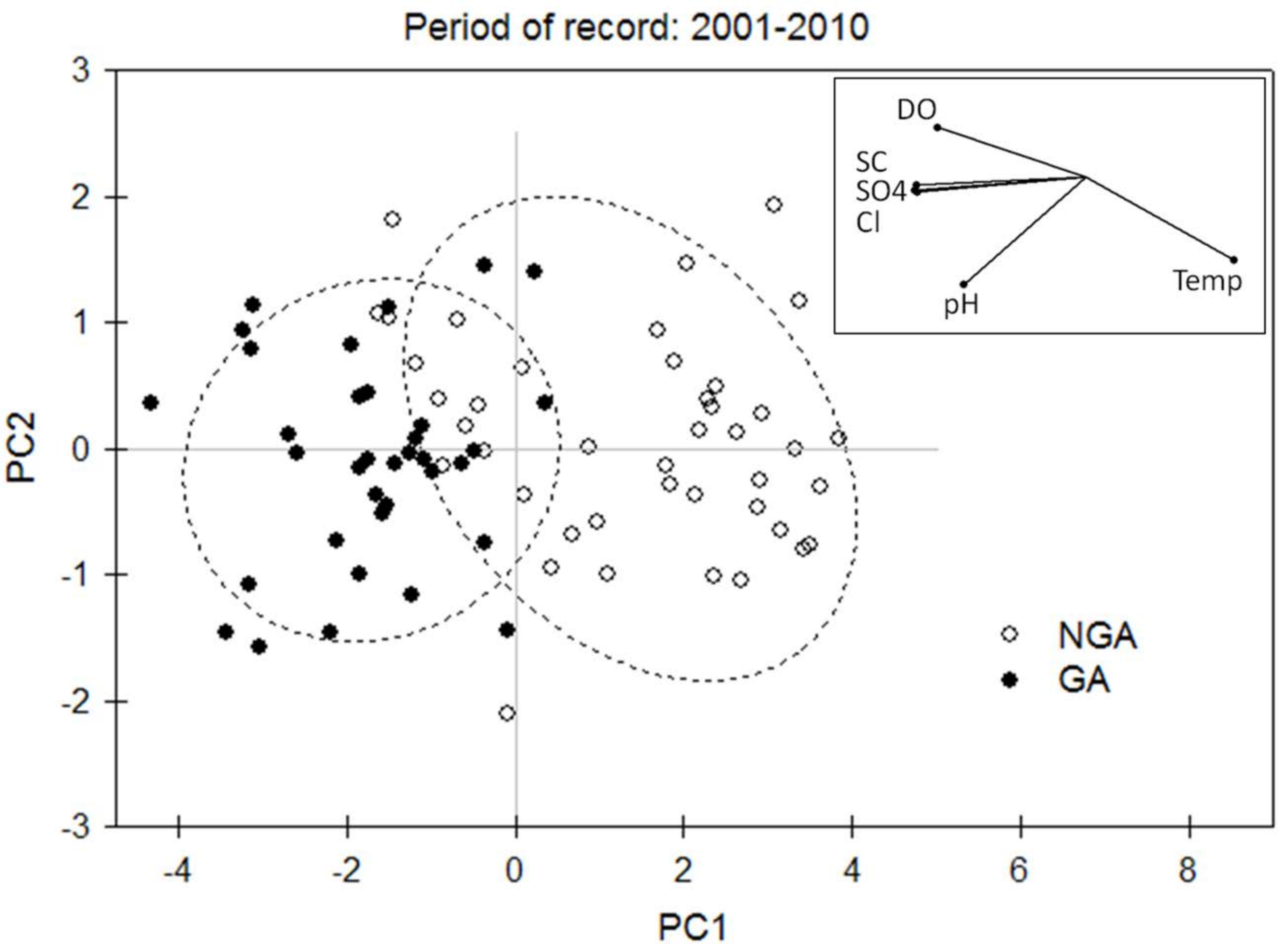
- Is it an invasive species in the United States?
  - Has it been always present and “appeared” only after water quality conditions became favorable?
  - What are the water quality conditions that favor colonization and growth?
    - ➢ Salinity
    - ➢ Nutrients

Retrospective Study of Reservoir Water Quality in Brazos and Colorado River: first blooms, 2001-2002



Patiño, R., Dawson, D., VanLandeghem, M.M. 2014. Retrospective analysis of the association between water quality and toxic blooms of golden alga (Prymnesium parvum) in Texas reservoirs: implications for understanding dispersal mechanisms and impacts of climate change. Harmful Algae 33: 1-11.

Principal Component Analysis of Water Quality



- Golden alga (GA) reservoirs are of higher salinity than non-golden alga (NGA) reservoirs
- No detectable differences in total phosphorus between GA and NGA reservoirs

Trend analysis of winter water quality: 1991-2010

Brazos River Watershed							
Parameter	**Statistics**	**Buffalo Springs Lake**	**Hubbard Creek Reservoir**	**Possum Kingdom Reservoir**	**Lake Granbury**	**Lake Whitney**	**Lake Waco**
Chloride (mg/l)	Tau	-0.238	0.289	0.255	0.203	0.436	-0.500
	Sen Slope	-8.375	5.369	16.440	35.862	16.293	-0.613
	Min, Med, Max	161, 321, 539	128, 240, 730	342, 732, 1331	231, 553, 1776	200, 341, 878	9, 17, 29
Dissolved Oxygen (mg/l)	Tau	NA	0.200	0.123	0.302	0.407	-0.083
	Sen Slope	NA	0.063	0.018	0.070	0.161	-0.010
	Min, Med, Max	NA	8.9, 10, 11.5	8.7, 9.9, 11.7	8.6, 10.4, 11.6	9.6, 10.9, 14.1	9.6, 10.6, 11.6
Hardness (mg/l of $CaCO_3$)	Tau	NA	0.071	-0.200	0.000	0.600	NA
	Sen Slope	NA	1.016	-5.856	-6.883	15.160	NA
	Min, Med, Max	NA	233, 277, 306	332, 39[illegible]	257, 343, 365	239, 286, 331	NA
Nitrate+Nitrite (mg/l)	Tau	NA	NA	[illegible]	NA	NA	NA
	Sen Slope	NA	NA	[illegible]	NA	NA	NA
	Min, Med, Max	NA	NA	[illegible]	NA	NA	NA
pH	Tau	0.552	-0.200	[illegible]	0.203	0.530	0.117
	Sen Slope	0.100	-0.007	[illegible]	0.003	0.024	0.006
	Min, Med, Max	7.9, 8.4, 8.7	6.3, 8.1[illegible]	[illegible], 8.4	8, 8.3, 8.5	7.8, 8.2, 8.4	7.9, 8.2, 8.7
Phosphorus (mg/l)	Tau	-0.195	N[illegible]	[illegible].022	-0.109	0.400	0.136
	Sen Slope	-0.001	[illegible]	0.000	-0.001	0.003	0.001
	Min, Med, Max	0.06, 0.08, 0.15	[illegible]	[illegible].03, 0.05, 0.13	0.04, 0.06, 0.16	0.03, 0.07, 0.09	0.03, 0.06, 0.15
Potassium (mg/l)	Tau	NA	[illegible]	0.200	0.400	NA	0.000
	Sen Slope	NA	0.2[illegible]	0.228	0.156	NA	0.022
	Min, Med, Max	NA	5.3, 7.3, 54.5	7, 7.8, 8.5	5, 5.6, 6.7	NA	1.7, 2.5, 3.8
Specific Conductance (µS/cm)	Tau	NA	0.333	0.380	0.281	0.143	NA
	Sen Slope	NA	70.402	46.288	83.021	39.270	NA
	Min, Med, Max	NA	456, 1151, 3025	1697, 2911, 3959	957, 2148, 4656	1048, 1673, 1790	NA
Sulfate (mg/l)	Tau	-0.524	0.018	-0.033	0.176	0.308	-0.500
	Sen Slope	-7.000	0.376	-0.576	4.089	5.073	-0.630
	Min, Med, Max	115, 240, 278	18, 80, 229	171, 345, 515	108, 242, 579	83, 164, 329	16, 25, 36
Temperature (C°)	Tau	-0.600	-0.382	-0.298	-0.425	-0.033	0.000
	Sen Slope	-0.077	-0.147	-0.102	-0.171	-0.055	-0.002
	Min, Med, Max	5.6, 6.4, 7.2	6.8, 9.2, 11.7	7.9, 10, 14.1	7.1, 10.5, 12.9	6.5, 10.1, 13.7	5.5, 11.1, 13.8

No trends

Trend analysis of winter water quality: 1991-2010

Colorado River Watershed							
Parameter	**Statistics**	**Lake Colorado City**	**Lake E.V. Spence**	**Twin Buttes Reservoir**	**Lake O.H. Ivie**	**Lake Buchanan**	**Lake Travis**
Chloride (mg/l)	Tau	0.200	-0.359	-0.378	-0.576	**-0.621**	**-0.579**
	Sen Slope	47.071	-43.333	-8.000	-16.237	**-3.567**	**-2.071**
	Min, Med, Max	466, 859, 1000	449, 1030, 1836	52, 108, 293	254, 375, 489	**36, 62, 114**	**25, 44, 137**
Dissolved Oxygen (mg/l)	Tau	0.467	0.436	-0.422	0.333	0.147	-0.021
	Sen Slope	0.231	0.201	-0.050	0.095	0.029	-0.005
	Min, Med, Max	9.6, 10.4, 12.3	6.1, 11.6, 13.5	8.7, 9.5, 10.2	9.5, 10.4, 11.9	9.1, 9.6, 10.7	8.1, 8.9, 9.4
Hardness (mg/l of $CaCO_3$)	Tau	NA	-0.111	NA	-0.378	NA	NA
	Sen Slope	NA	-14.000	NA	-10.167	NA	NA
	Min, Med, Max	NA	588, 688, 960	NA	427, 499, 572	NA	NA
Nitrate+Nitrite (mg/l)	Tau	NA	-0.431	[illegible]	-0.018	0.176	0.158
	Sen Slope	NA	-0.004	[illegible]	-0.001	0.003	0.003
	Min, Med, Max	NA	0.02, 0.05, 0.4	[illegible]	0.09, 0.22, 1.08	0.03, 0.16, 0.58	0.08, 0.15, 0.45
pH	Tau	0.067	0.364	[illegible]	-0.030	-0.074	-0.265
	Sen Slope	0.023	0.017	[illegible]	0.000	-0.003	-0.006
	Min, Med, Max	8.3, 8.6, 8.8	7.8, 8.4, [illegible]	[illegible]3.6	8, 8.2, 8.3	8, 8.1, 8.4	7.9, 8.1, 8.3
Phosphorus (mg/l)	Tau	NA	0.[illegible]	[illegible]295	0.122	0.075	0.271
	Sen Slope	NA	[illegible]	-0.003	0.000	0.000	0.001
	Min, Med, Max	NA	0[illegible]	[illegible].06, 0.09, 0.12	0.02, 0.06, 0.07	0.02, 0.06, 0.24	0.01, 0.05, 0.21
Potassium (mg/l)	Tau	NA	[illegible]	NA	NA	NA	NA
	Sen Slope	NA	[illegible]	NA	NA	NA	NA
	Min, Med, Max	NA	NA	NA	NA	NA	NA
Specific Conductance (µS/cm)	Tau	0.200	-0.242	-0.244	-0.394	**-0.632**	**-0.642**
	Sen Slope	81.682	-93.682	-30.000	-42.382	**-18.488**	**-8.794**
	Min, Med, Max	4396, 5014, 6232	2034, 3486, 5194	435, 724, 1432	1298, 1888, 2350	**413, 559, 962**	**407, 479, 903**
Sulfate (mg/l)	Tau	NA	-0.410	-0.422	-0.424	**-0.611**	**-0.526**
	Sen Slope	NA	-40.146	-4.500	-7.847	**-2.249**	**-1.067**
	Min, Med, Max	NA	296, 692, 1344	26, 43, 112	201, 296, 376	**20, 38, 84**	**17, 26, 100**
Temperature (C°)	Tau	-0.733	-0.410	-0.244	-0.152	0.000	0.021
	Sen Slope	-0.698	-0.268	-0.217	-0.122	-0.004	0.010
	Min, Med, Max	9.4, 10.6, 14	5.8, 8.1, 11.3	9.2, 11.5, 13.4	6.4, 9.6, 11.6	10.7, 12.6, 15	13.4, 15.3, 18.3

No trends

Conclusions from Brazos/Colorado Study

- Eutrophic conditions and salinity >0.5-1 psu favor toxic blooms of golden alga in reservoirs of the Brazos (0.5 psu) and Colorado (1 psu) Rivers

- Such conditions pre-date onset of blooms (in 2001-2002) by more than 10 years, and in some cases by several decades

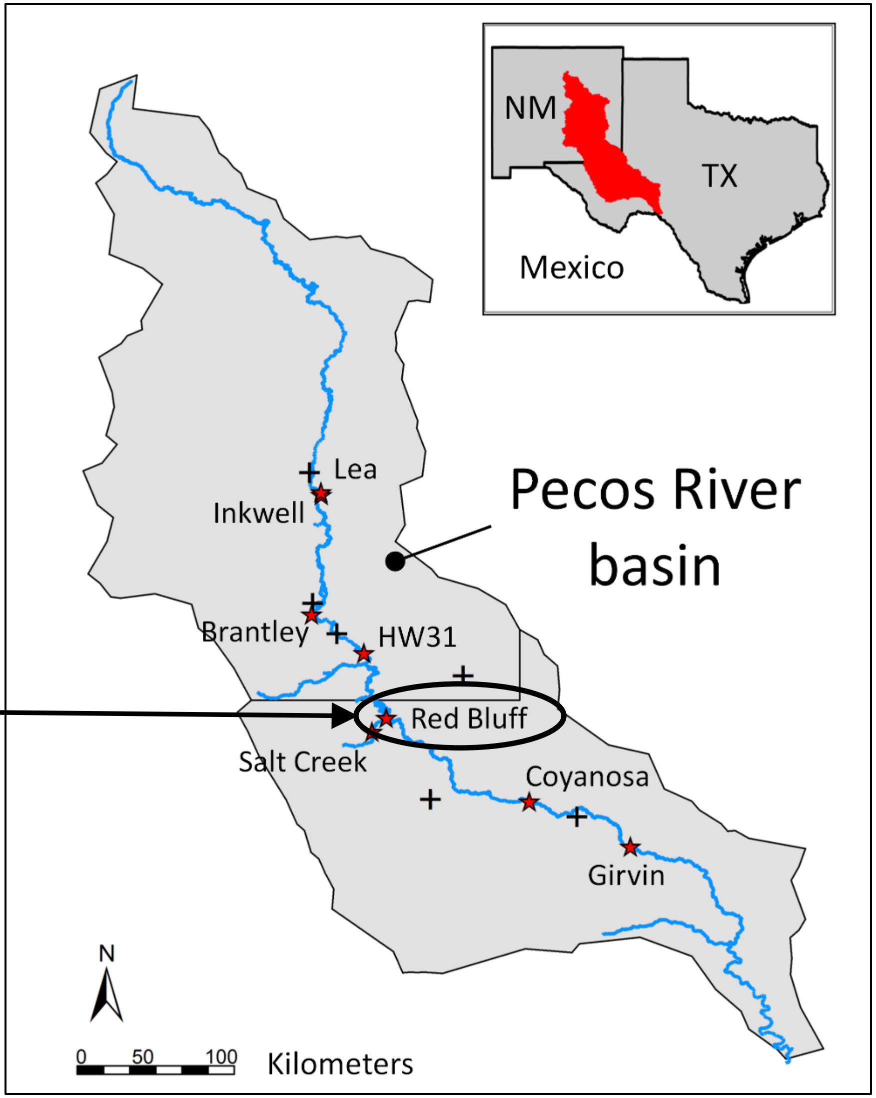
- These observations are consistent with novel introduction (invasion) of golden alga into Brazos and Colorado River reservoirs sometime before toxic blooms were first observed

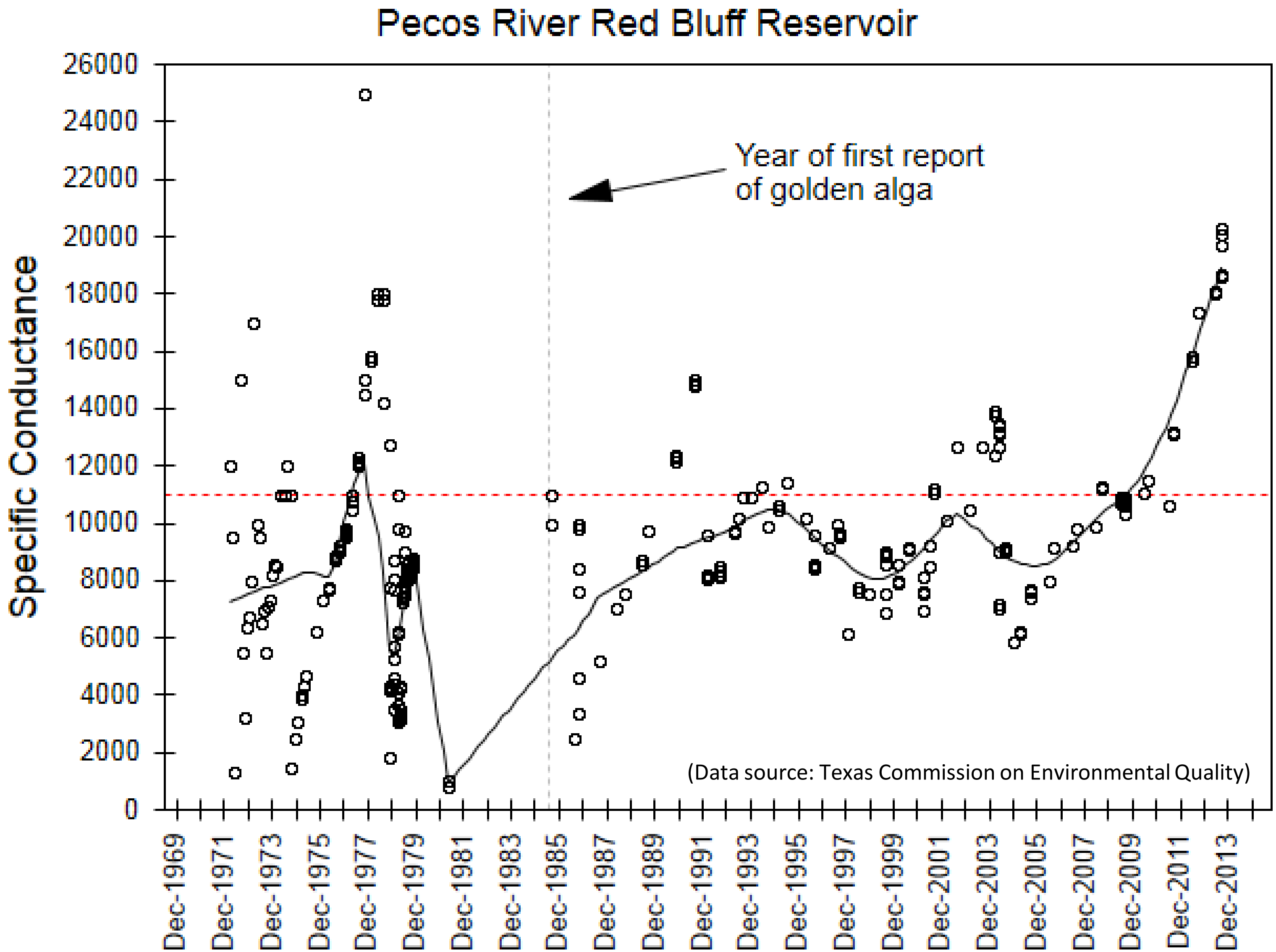
Pecos River?

Epicenter of Golden Alga Blooms in Western Hemisphere

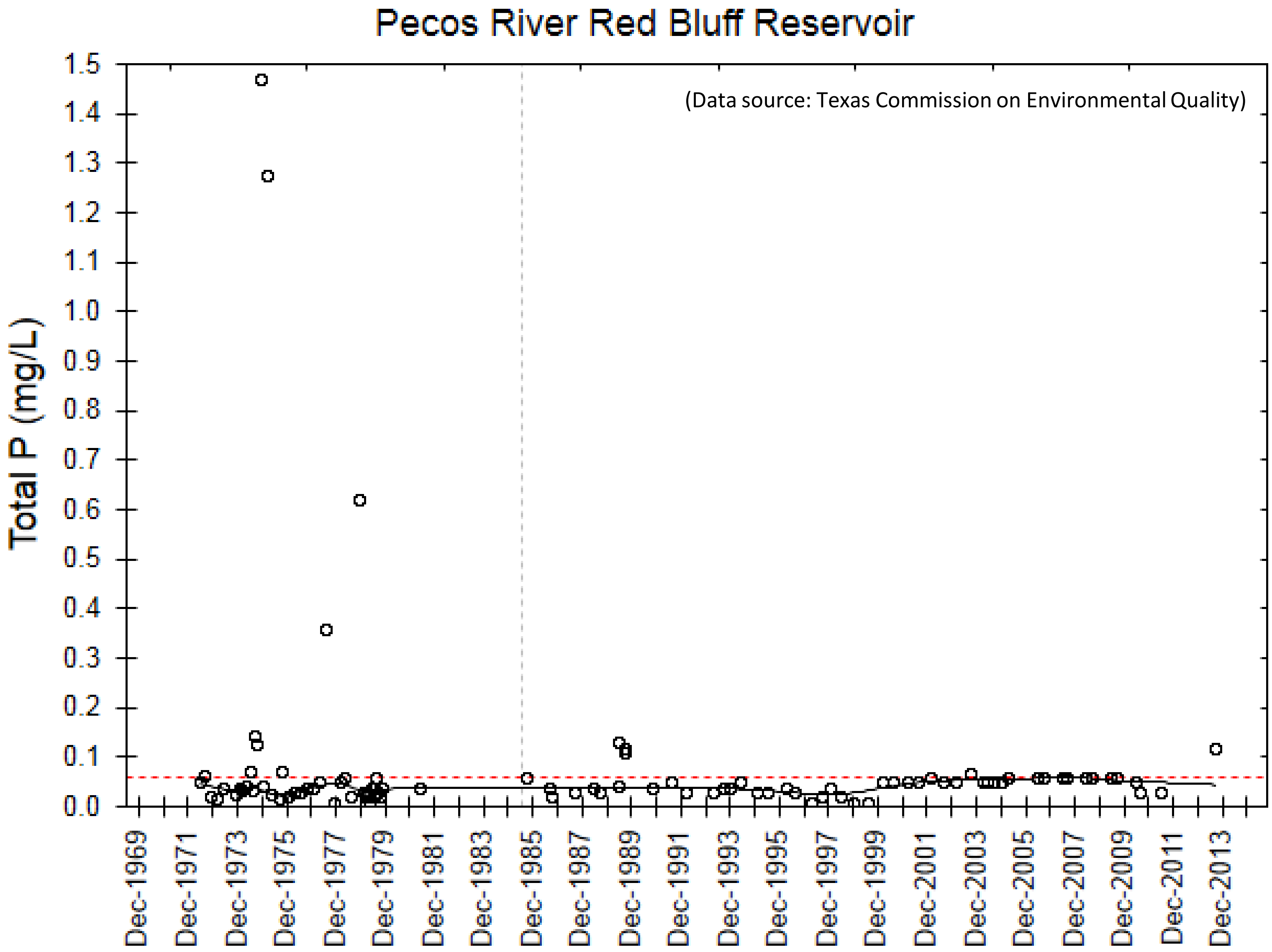
- Were there any trends in water quality prior to 1985, the year of the first toxic bloom in this basin?

Red Bluff Reservoir





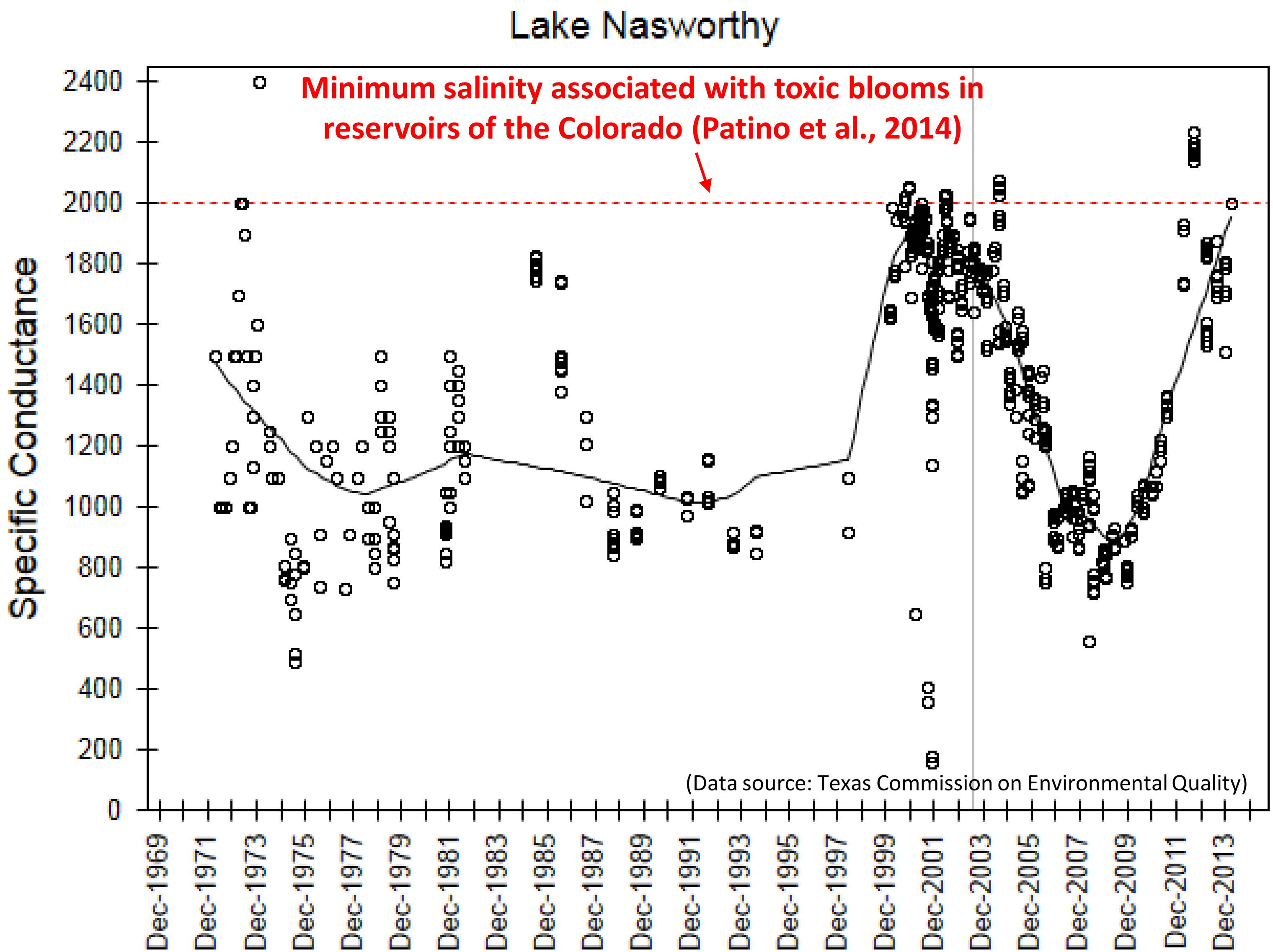
- Like Brazos and Colorado reservoirs, salinity conditions that favor golden alga (about 2000 µS/cm) pre-date the onset of toxic blooms in Red Bluff



- Like Brazos and Colorado reservoirs, no increasing trend in total phosphorus is evident prior to onset of toxic blooms in Red Bluff

“Latent” Populations of Golden Alga

- Several reservoirs in Texas have golden alga in low abundance, without production of toxic blooms (Patino et al., 2014)
- As conditions change due to anthropogenic influences (landcover or climate change), could golden alga develop toxic blooms in these reservoirs?
- …
- Lake Nasworthy in the Colorado River (Texas)
    - Golden alga was first detected in 2003 but toxic blooms were not observed until winter of 2014



- In 2003, salinity was on the decline from peak values around 2000-2001
- By 2014, salinity had bounced back to levels associated with toxic blooms in the Colorado River basin
- Consistent with colonization in early 2000s

Summary

- Golden alga typically blooms in eutrophic-to-hypereutrophic reservoirs with salinity of 0.5-1 psu
- In most Texas reservoirs affected by golden alga, these conditions pre-date by many years (>10 years or longer) the first record of toxic blooms
- In at least one Texas reservoir (Nasworthy), golden alga was present >10 years before a toxic bloom was recorded
    - Possible reason: salinity may have been suboptimal at time of colonization
- These observations are consistent with golden alga being an invasive species that colonized Texas surface waters near the time when toxic blooms were first observed or the alga first detected at the affected locations
- Genetic studies of golden alga strains from around the world support this scenario (Lutz-Carrillo et al., 2010)

Monitoring Options

- Golden alga abundance (density)
  - Hemocytometer
    - ✓ standard method, simple
    - ✓ not very sensitive (limit of detection, 1000 cells/mL), but this may not be a problem for monitoring because blooms < 10,000 cells/mL typically not toxic
  - PCR (DNA analysis) – sensitive but requires laboratory procedures
- Golden alga toxicity
  - Laboratory bioassay – standard method, requires laboratory procedures, no other methods currently available
- Our laboratory is currently developing predictive models of toxicity based on hemocytometer counts and water quality measurements (VanLandeghem et al., in review and in preparation)

Treatment Options

- A number of treatments have been developed for small water bodies, such as fish ponds, that seem to work fairly well:
  - For example, addition of inorganic nitrogen (ammonia) or inorganic phosphorus reduces golden alga density and toxicity (Kurten et al., 2011)
- Whole-reservoir treatment options are not fully developed at present, but several strategies have been proposed for smaller areas or coves within reservoirs to serve as refugia for aquatic life (Roelke et al., 2012), including:
  - Hydraulic flushing – using bottom waters recycled to the surface (Hayden et al., 2012)
  - pH manipulation – toxicity high at basic pH, eliminated at neutral pH
  - Ammonia treatment

Thank you

Questions?