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Arkansas Department of Environmental Quality  
5301 Northshore Drive  
North Little Rock, AR 72118

October 28, 2016

RE: Phase I Input on 2018 Assessment Methodology

Dear Director Keough, Commissioners and ADEQ Water Planning Branch:

Thank you for the opportunity to provide input on the 2018 Assessment Methodology. On March 15, 2016 I submitted comments on the Proposed 2016 Impaired Waterbodies List, which include comments from Ms. JoAnn Burkholder. I request that the comments submitted on the Proposed 2016 Impaired Waterbodies List be taken into consideration when revising the 2016 Assessment Methodology. These comments are attached. A few broad areas of review for Phase I that we would like to have reviewed are...

- The 2018 Assessment Methodology should use the best science available and all evaluation protocols should be science based
- The sufficiency of the amount of data that is collected, monitored and analyzed
- The antidegradation policy and inclusion of an antidegradation implementation procedure
- Improvement of ADEQ’s statistical, scientific and analytical capabilities

Thank you for the opportunity to provide comments and starting the stakeholder process for the 2018 Assessment Methodology.

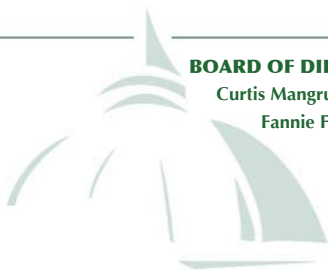
Sincerely,  
Anna Weeks  
Environmental Policy Associate

(Attachment)

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**Comments on the Draft: *Assessment Methodology for the Preparation of The 2014 Integrated Water Quality Monitoring and Assessment Report, and The 2016 Water Quality Monitoring and Assessment Report, authored by the Arkansas Department of Environmental Quality (ADEQ)***

**JoAnn M. Burkholder, Ph.D., 15 March 2016**

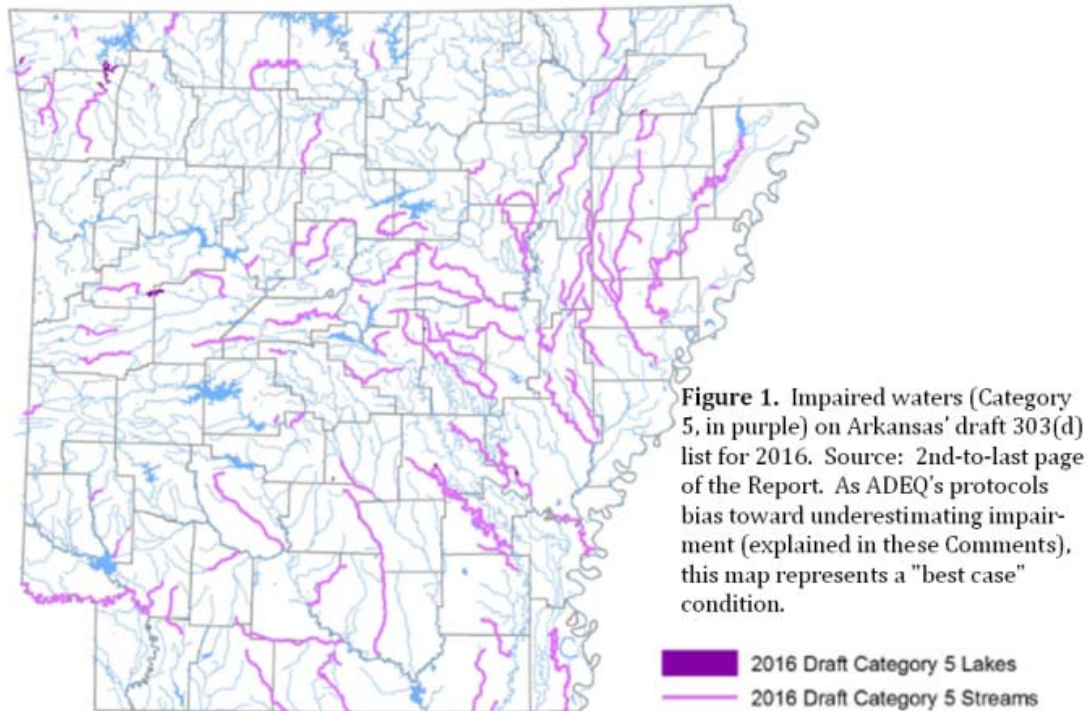
My comments on the draft report, *Assessment Methodology for the Preparation of The 2014 Integrated Water Quality Monitoring and Assessment Report, and The 2016 Water Quality Monitoring and Assessment Report*, hereafter referred to as the Report, were requested by Ms. Anna Weeks, Environmental Policy Associate of the Arkansas Public Policy Panel. These comments represent my professional opinion as a specialist with more than 30 years of experience in water quality analysis and assessment. An updated copy of my curriculum vitae is attached.

***Overall Evaluation***

The designated uses of Arkansas surface waters include use by Aquatic Life, and uses for Domestic Water Supply; Primary and Secondary Contact; and Agricultural and Industrial Water Supply (Report, p.24). A total of 87, 617 stream and river miles occur in the state (p.20), but only 18% (16,135 miles, p.18) are digitized in the Arkansas Department of Environmental Quality (ADEQ) Water Base Layer, suggesting that only 18% are monitored. It is doubtful, based on the Report, that even 18% are actually monitored, considering that the writing (p.23) states that “Monitoring segments without stations, where data from another segment is used for evaluating attainment, are identified as ‘evaluated’ ....for tracking purposes.” Thus, most Arkansas waters are not monitored despite indication, from the relatively few that *are* monitored, that many of the state’s surface waters are impaired (see Figure 1 on the next page of these Comments).

The U.S. Environmental Protection Agency (EPA 2005) describes assessments based on larger sample sets as more likely to yield accurate conclusions than assessments based on smaller sample sets, while also recognizing difficulties that can be imposed by expense and logistics (U.S. EPA 2002). Unfortunately, however, Arkansas has taken reliance upon sparse data to an extreme; ADEQ sanctions sampling numbers and frequencies that are seriously inadequate and do not enable accurate assessment. The sparse data deemed acceptable for evaluation of use attainment bias the findings against impairment.

There are numerous other non-science-based steps in ADEQ’s evaluation protocols. As examples, some integrated reporting categories, by definition, fail to provide protection to impaired waters and instead can allow them to continue to degrade indefinitely. The Biological Integrity Assessment protocol wrongly “transforms” substantially compromised Partially Supporting communities into a “Fully Supporting” designation. For fish communities, the assessment protocol evaluates substantially decreased taxa richness, the loss of sensitive aquatic life, and increased abundance of pollution-tolerant species as “supporting” designated uses for Aquatic Life, again wrongly resulting in a “Fully Supporting” overall assessment. The dissolved oxygen (DO) standard for reservoirs is applied by ADEQ only to near-surface waters (depth, 1 meter); yet, hypoxia generally occurs first in



the bottom waters and then increasingly affects shallower waters as the critical summer season progresses (Wetzel 2001). Thus, nearly the entire water column of a given impoundment ("lake") would have to become hypoxic or anoxic before a violation of the standard would occur – and, because ADEQ has monitored the state's reservoirs only once in five years, such extreme conditions could occur during the summer critical period for four years before any sampling would be conducted. Streams with small watersheds (defined as having an area less than 10 square miles) anywhere in the state, even in the Ozark Highlands, are evaluated as having "acceptable" water quality during the critical summer season if DO is at an hypoxic level (2 mg/L) which repeatedly has been shown to cause death of many biota. Small headwater streams, known to be extremely important to river ecosystems of Arkansas, have been decreed by ADEQ without scientific basis to have insufficient flow to warrant higher DO criteria during the critical summer period. Despite asserting otherwise, the state has **no** numeric nutrient (quantitative nitrogen and phosphorus) criteria and the Report indicated no plans to develop them. Moreover, ADEQ's seriously inadequate assessment protocol for nutrient-related impairment will fail to protect many actually-impaired Arkansas surface waters from loss of designated uses due to nutrient pollution. The analysis in support of this overall evaluation is given below.

### ***Supporting Analysis***

- 1. Integrated reporting Categories 4b, 5-medium, and 5-low fail to provide protection to impaired waters and instead allow them to continue to degrade indefinitely.***

Arkansas has considered U.S. EPA (2011) guidance in using five "integrated" reporting categories for monitored waterbody segments in that state:

- Category 1 – all designated uses attained, no use threatened;
- Category 2 – available data/information indicate that some, but not all, designated uses are supported;
- Category 3 – insufficient data/information available to evaluate attainment;
- Category 4 – water quality standards are not attained for one or more designated uses, but a total maximum daily load (TMDL) is not required because (a) a TMDL has already been completed; (b) other pollution control requirements are expected to result in attainment; or (c) non-support is not caused by a pollutant; and
- Category 5 – the waterbody is impaired, and one or more water quality standards not attained.

ADEQ then went beyond the above U.S. EPA-recommended categories by devising three subdivisions within Category 5 including:

*High* – “truly impaired:” a TMDL should be developed or other corrective action(s) taken;

*Medium* – the waterbody is not presently attaining water quality standards, but it may be delisted if the state revises its water quality standards in the future; and

*Low* – the waterbody is not attaining one or more water quality standards, but all designated uses are determined to be supporting; or there is insufficient data to assess attainment; or ADEQ assessed the waterbody as not impaired, but the U.S. EPA assessed it as impaired.

The Category 4(b) designation provides no description about the waiting (delay) period that is “acceptable” (months? years?) before actions will be required to improve the impaired waterbody. ADEQ’s “medium” subcategory within Category 5 is similarly problematic; it allows no cleanup indefinitely, simply based on the premise that the state *may* revise the water quality standard(s) in violation at some vague future date. Lack of protection for surface waterbodies similarly characterizes subcategory “Low” within Category 5. Waters that are known to be in violation of one or more water quality standards are considered low priority for cleanup if ADEQ assesses all designated uses to be supported. However, the sampling upon which ADEQ’s assessment is based is inadequate to enable sound scientific evaluation, and it is biased against finding impairment (see #2 below). Alternatively, waters assessed as impaired by the *U.S. EPA* are prioritized “Low” for cleanup if ADEQ considers them unimpaired, with no further explanation as to how/why the state and federal assessments diverged. Thus, ADEQ states here that it can all-but-ignore (that is, prioritize “Low”) a federal assessment of “impaired.”

A third alternative under Category 5 that results in consideration of an impaired waterbody as “Low” priority for cleanup requires clarification: The waterbody will be so prioritized if there are insufficient data to make a scientifically defensible decision regarding attainment of designated uses. – Yet, why would such waters be evaluated as impaired if the data are insufficient to assess attainment? Why would they not instead be designated as Category 3? One answer may be that such waterbodies are clearly, visually impaired – for example, characterized by high-biomass algal outbreaks (“blooms”) and major fish kills – but measurements have not been taken. It would seem important to the people of Arkansas to prioritize waters that are clearly, visually impaired as “High” rather than “Low” for data gathering and cleanup.

2. *The required sample numbers and sampling frequency are inadequate and, thus, do not enable accurate condition assessment.*

a) *Quarterly or bimonthly sampling is inadequate to assess attainment of water quality criteria and designated uses.*

Accurate assessment of water quality critically depends upon adequate monitoring (Burkholder et al. 2010, Reed et al. 2010). In its protocols to assess use attainment, ADEQ uses exceedingly sparse data to attempt to assess “average” conditions, compliance with water quality criteria, and use attainment. These exceedingly sparse data are not based in science. The Report (p.13) describes two tiers of data (Tiers III and IV) that are used for assessment of attainment of designated uses in a given waterbody. These tiers allow quarterly (III) or bimonthly (III, IV) sampling during key periods (e.g. the summer season for low DO). However, quarterly or bimonthly sampling is inadequate to assess attainment of water quality criteria and designated uses. Quarterly data are insufficient to assess average conditions in surface waters because they miss many storm events and associated higher nutrient concentrations, as well as drought periods with substantially altered water quality, which would be detected with more frequent sampling (Stansfield 2001, Hollabaugh and Harris 2004).

For determining whether a waterbody is meeting state criteria and attaining its designated uses, a body of science publications has shown that data collected at least monthly during the same growing season of the same year, then repeated the next year, are needed to assess conditions accurately (e.g. Harmeson and Barcelona 1981, Robertson and Roerish 1999; U.S. EPA 2000a,b; Stansfield 2001; Hollabaugh and Harris 2004). Assessment of average conditions should also encompass baseflow, stormflow, and wetflow conditions (Hollabaugh and Harris 2004). Only a few data points over an entire year (ADEQ accepts only 2 per year; see #2b below) are inadequate to accurately assess compliance with criteria or impairment. As Stansfield (2001) noted, if sampling frequency is changed from monthly to quarterly, many statistically significant trends detected from the monthly water quality data “disappear.”

For Tier III data, the report (p.13) states that “limited use” of continuous monitoring instruments is sufficient, but provides no information as to the actual amount of sampling that is acceptable to ADEQ. When this point is considered together with what ADEQ views as acceptable temporal coverage (“adequate to monitor for chronic conditions...”), such a vague description translates into waterbodies so inadequately sampled that impairment would easily be missed. For example, consider a waterbody that is actually impaired by low DO, with pre-dawn oxygen sags common over much of the mid- to late summer but not the early summer. Pre-dawn is the time of day when low DO conditions usually are worst, that is, when aquatic organisms are most vulnerable to stress and death from low DO (Hynes 1980, Morgan et al. 2006, Miltner 2010). If ADEQ regards one to a few diel (24-hour) periods to be an acceptable amount of “limited use” of continuous monitoring instruments during the critical summer season, and if the 24-hour periods are selected to be in *early* summer, then severe low DO impairment that occurs throughout much of the summer would be entirely missed (e.g. Morgan et al. 2006). The waterbody would be evaluated as “attaining” its designated uses when, in reality, cryptic early life history stages of beneficial aquatic life would die unnoticed throughout the mid- to late summer from undetected low DO conditions; recruitment failure of many species would occur; and no protective cleanup would be planned.

- b) *As few as 10 water quality samples, over as long as 5 years, is inadequate to assess average conditions accurately, or to determine whether a waterbody supports its designated uses.*

ADEQ (Report, p.10) relies upon as few as 10 water quality samples, over as long as 5 years, to assess whether a given waterbody supports its designated uses. This sampling is seriously inadequate to enable accurate assessment (see references cited in comment #2 above), requiring only 2 samples per year. It is not science-based, as it would easily miss stormwater runoff, baseflow conditions, pollutant spills, algal outbreaks, and other stochastic events that strongly control the true “average” conditions. The approach by ADEQ to rely upon extremely sparse data does not enable even “somewhat” realistic assessment of use attainment. ADEQ’s approach instead strongly biases the findings against impairment.

3. *The protocol for assessment of Biological Integrity does not stipulate that temperature extremes should be avoided during data collection, and does not account for inter-annual variation which can be substantial, even extreme.*

The report describes assessment of only one biological assemblage (Tier III) – either macro-invertebrates or fish – over at least two seasons as acceptable by ADEQ for assessment of Biological Integrity. There is no requirement that the seasons should be selected so as to avoid temperature extremes (Maxted et al. 2000). Data collection over two years is described as preferable, but it is not required; thus, there is no effort to address or account for inter-annual variation, which can be substantial (Resh and Rosenberg 1989). Acute and chronic toxicity tests of vertebrates (fish) and (macro)invertebrates are considered if available, but they are not required either for use assessment (Report, p.26).

4. *The Biological Integrity Assessment protocol fails to protect already-impaired surface waters because substantially compromised Partially Supporting communities are wrongly “transformed” into a Fully Supporting designation.*

ADEQ (Report, p.28) considers four categories of status in evaluating macroinvertebrate assemblages:

Comparable to Reference (by 90% or more) = expected to support the community structure present at the reference site.

Supporting (75-88% comparable to reference site) = should support a diverse community similar to that at the reference site.

Partially Supporting (60-73% comparable to reference site) = difference in the biological community may be due to poor habitat; comparisons may be difficult.

Non-supporting (< 58% comparable to reference site) = should not be expected to support the community present at the reference site.

Scrutiny of the above descriptions shows that “partially supporting” is poorly described. Readers are informed that ‘one cannot be certain’ as to why the scores indicate that the macroinvertebrate communities are only 60-73% comparable to the healthy macroinvertebrate community at the reference site. Readers are also informed that ‘comparisons [to the reference community] may be

difficult' due to poor habitat. Poor habitat, however, frequently includes poor water quality (Rebich et al. 2004); yet, the strong possibility/probability that the compromised scores at least partly reflect poor water quality is not mentioned here by ADEQ. A macroinvertebrate community that only includes 60% of the species richness and/or abundance of those attributes at the reference site is considerably compromised. After all, Partially Supporting is the same as "Partially Not Supporting."

The Partially Supporting category "suddenly" becomes "Supporting" (S) in the final evaluation, as shown in Table XI (Report, p.30): The substantially compromised macroinvertebrate community designated as only Partially Supporting "disappears" and the overall evaluation becomes either "Fully Supporting" or Non-Support (see Table XI of the Report, reproduced below as Table 1 of these Comments).

**Table 1.** Aquatic Life Designated Use Listing Protocol (Table XI in the Report).

Type of Data Present	Evaluation Result		Final Assessment	Listing Category
	Fish Community	Macroinvertebrate Community		
Fish Community and/or Macroinvertebrate Community	S	S	FS	1
	S	NS	NS	5
	NS	S	NS	5
	NS	NS	NS	5
At Least One Biological Community	S	NA	FS	1
	NA	S	FS	1
	S	S	FS	1
	NA	NA	UA	3
	NS	NA	NS	5
	NA	NS	NS	5

S = Support NS = Non-Support FS = Fully Supporting NA = No Available Data UA = Unassessed

This "sleight of hand" fails to protect already-substantially-compromised communities from further degradation. Instead, it obscures substantially compromised, only-partially-supporting (or, said another equally valid way, partially non-supporting) communities and then artificially "changes" them to "S", "Supporting." There is no science-based rationale for this step by ADEQ to quietly ignore Partially Supporting macroinvertebrate communities and wrongly evaluate them as "supporting," then as "fully supporting."

**5. The Biological Integrity assessment protocol is not protective of fish communities because it evaluates decreased taxa richness and loss of sensitive aquatic life as wholly "supporting" designated uses.**

The fish community structure indices (Report, p.29) show total score ranges and categories for each of several designated ecoregions. The scores and categories apparently are applied across ecoregions. For example, non-delta scores for watersheds larger than 10 square miles in area are as follows:

mostly similar	25-32 (highest score or healthiest fish community)
generally similar	24-17
somewhat similar	16-9
not similar	8-0

Note that streams draining watersheds smaller than 10 square miles in area, which include ecologically important, perennial headwater streams (as well as ephemeral streams), apparently are not evaluated (and see Comment #6b below).

According to Table X (p.30), assessment of use attainment support based on fish communities considers both “mostly similar” and “generally similar” categories (note the vague descriptions) to be acceptable or “supporting.” A score as low as 17 out of 32, only a little more than half of the total scale, leads to an overall assessment of “supporting.” “Generally similar” is described as:

“Community structure less than expected. Taxa richness lower than expected.  
Some intolerant taxa loss. Percent contribution of tolerant forms may increase.”

Thus, the approach is not protective because it sanctions loss of species diversity, loss of sensitive species, and an increase in pollution-tolerant forms as “acceptable” or supporting, which the protocol then “translates” to an overall evaluation of “fully” supporting as shown in Table XI.

**6. *Certain important features of the Arkansas dissolved oxygen criteria are neither science-based nor protective of the state’s surface waters.***

- a) *The reservoir DO criterion applies only to near-surface waters (depth 1 meter) and, thus, fails to protect beneficial aquatic life in lower-water-column and benthic (bottom) habitats.***

Hypoxia/anoxia much more commonly and severely impact aquatic life in benthic and lower-water-column habitats than in near-surface waters (Wetzel 2001). Hypoxic conditions typically begin in deeper waters and sediments, then spread to impact aquatic life in mid-depth waters. Very rarely – even when most of the water column is hypoxic or anoxic – does hypoxia/ anoxia impact near-surface waters, for two reasons. First, those waters are closest to the overlying air, which is an important *source* of oxygen to them (Wetzel 2001). Second, algae and plants usually are most abundant in near-surface waters, and their photosynthesis increases the DO during the day (Wetzel 2001, Burkholder and Glibert 2013) when measurements typically are taken. Thus, a DO criterion applied only to a depth of 1 meter means that nearly the entire reservoir water column would have to become hypoxic/anoxic before the Arkansas DO criterion would indicate impairment.

- b) *A hypoxic DO concentration of 2 mg/L, known to severely stress and kill many aquatic species, is irrationally “acceptable” for ecologically important, small perennial headwater streams throughout the state . This standard is not science-based.***

Headwater streams repeatedly have been shown to be vitally important to entire river ecosystems (Leopold et al. 1964 in Allen and Castillo 2007). As Meyer et al. (2007, pp.86,98) wrote,

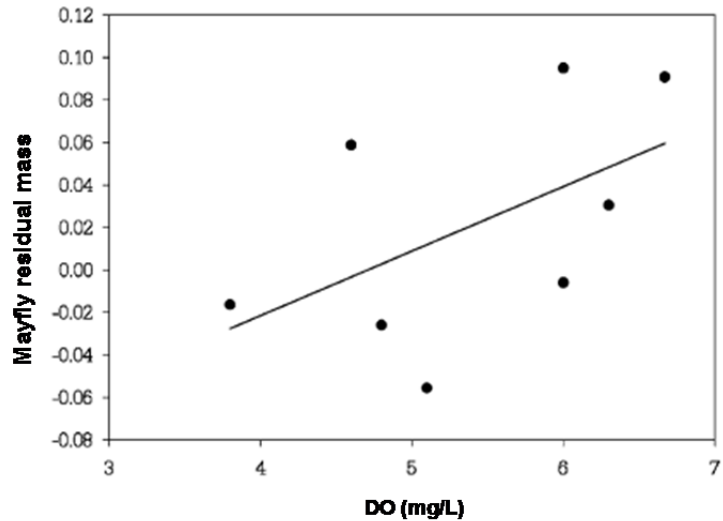
The influence of headwaters on downstream systems emerges from their attributes that meet unique habitat requirements of residents and migrants by: offering a refuge from temperature and flow extremes, competitors, predators,



and introduced species; serving as a source of colonists; providing spawning sites and rearing areas; being a rich source of food; and creating migration corridors throughout the landscape. *Degradation and loss of headwaters and their connectivity to ecosystems downstream threaten the biological integrity of entire river networks* [emphasis added]....Biological connectivity between headwater and downstream ecosystems is considerable and essential for the maintenance of species diversity in downstream ecosystems.

During summer, these small 1<sup>st</sup> to 3<sup>rd</sup> order streams in some regions of Arkansas can be reduced to a series of enduring pools as a natural hydrologic progression (Hedman et al. 1987, Taylor and Warren 2001, Woods et al. 2004).

Densities of aquatic insects and fishes have been reported to increase as the pools become more isolated (Williams et al. 2003). Pools in these streams can vary greatly in DO, ranging from well above 5 mg/L to hypoxic at ~3.5 mg/L in summer (e.g. Figure 2). In other areas, however, such as the Ouachita Mountains and Ozark Highlands, small streams remain DO-replete (Woods et al. 2004). Some small streams in Arkansas are perennial, meaning that flow generally is maintained throughout the critical summer period. The natural flows which maintain high biological diversity in DO-replete, shallow waters of these streams can be well below 1 cfs (Hedman et al. 1987, Woods et al. 2004).



**Figure 2.** Linear regression between DO and body condition of low-DO-sensitive mayfly larvae from isolated pools in the Alum Fork of the Saline River (summer 2002). Measurements of DO were averaged across months (June-July). From Love et al. (2005).

The Report contains the following DO criterion for small perennial headwater streams draining watersheds less than 10 square miles in area. These **perennial** (= naturally flowing all year) streams, encompassing both first-order and second-order streams (Table 2) are considered together with ephemeral (intermittent) streams, without scientific basis. Rather than being protected from hypoxia during the critical summer season, they are **assigned** a “severe hypoxia” standard:

In streams with watersheds less than 10 square miles, it is **assumed** [emphasis added] that insufficient water exists to support a fishery during the critical season. During this time, a DO standard of **2 mg/L** [emphasis added] will apply to prevent nuisance conditions....

ADEQ (Report, p.38) defines “insufficient water” as a stream having less than 1 cubic foot per second (cfs) of flow. Considering the science of small streams as summarized above, the ADEQ definition is not science-based and makes no sense scientifically. Many small streams in Arkansas

are known to maintain high biological diversity during the critical summer season; many have DO-replete conditions; and most are either perennial with lower average summer flows than 1 cfs, or intermittent but with enduring, DO-sufficient pools. Yet, ADEQ's definition "forces" these streams to either flow at 1 cfs or higher, or be subjected to extreme hypoxia (see U.S. EPA information below) as an assigned minimum criterion.

ADEQ then requires stream-by-stream, individual site-specific "field site verification" to prove that "aquatic life exists at flows below 1 cfs" (although aquatic life is well known to exist in perennial streams with flow less than 1 cfs, worldwide) or that "unique aquatic biota [are supported in] "significant groundwater flows or enduring pools," before the waterbody is afforded protection by a higher DO standard.

Thus, *a priori* the DO criterion applied during the critical summer season to small streams draining watersheds less than 10 square miles in area is severely hypoxic (U.S. EPA, "Hypoxia 101," <https://www.epa.gov/ms-htf/hypoxia-101>). Exceptions are only made on a site-specific basis, only after field verification. According to "Hypoxia 101" by the U.S. EPA, "Hypoxic waters have dissolved oxygen concentrations of less than 2-3 ppm [mg/L]." Another U.S. EPA publication defines hypoxia as 3 mg DO/L or less (see <http://omp.gso.uri.edu/ompweb/doee/science/physical/choxy1.htm>), in close agreement with "Hypoxia 101."

Most temperate fishes begin to exhibit respiratory distress at dissolved oxygen levels of ~2.3 mg/L or less (Davis 1975, and references therein; also see Friedrich et al. 2014, Jenny et al. 2015). This DO criterion of 2 mg/L would be expected to stress or kill sensitive life history stages of all but the most tolerant species in small perennial streams. For example, based on an investigation of fish assemblages at 35 sites in lowland streams near Arkansas (southwestern Louisiana), a DO minimum of 2.5 mg/L was needed to maintain all but the most low-oxygen-tolerant species (Justus et al. 2012).

7. *Arkansas criteria for Escherichia coli in surface waters sanction **much** higher fecal bacteria densities than the threshold criteria recommended by the U.S. EPA (2012) to protect human health safety. Moreover, the Arkansas criteria allow violations of those criteria in up to 25% of samples as "acceptable"*

The Report (Table XIII, p.42, excerpted on the next page of these Comments) indicates that "acceptable" criteria for *E. coli* densities in Arkansas waters for primary contact range from a geometric mean (GM) of 126 colonies (col, or colony-forming units) per 100 mL in ERWs, ESWs, and NSWs, to 298-410 col per 100 mL during the May-Sept. recreational period. In secondary contact waters, the "allowable" criteria for *E. coli* densities include a GM of 630 col per 100 mL in ERWs, ESWs, and NSWs; 1,490 col per 100 mL throughout the year in reservoirs; and 2,050 col/100 mL throughout the year in all other waters (rivers, streams, etc.). As the table also shows, up to 25% of the GMs, or up to 25% of the samples, can exceed these remarkably high standards and the waterbody is still evaluated as "acceptable."

As shown, the U.S. EPA (2012)- recommended *E. coli* densities to protect human health safety are significantly lower (that is, significantly more protective of human health safety) than the

Arkansas values. The available information indicates that the Arkansas criteria allow, as “acceptable,” a much higher estimated human illness rate than that of the U.S. EPA, i.e., much higher than 32 people becoming sick per 1000 exposed. Moreover, with exception of ERWs, ESWs, and NSWs, the Arkansas criteria allow even those high *E. coli* densities to be exceeded up to 25% of the time for GMs, or for up to 25% of the samples taken. This stipulation makes the criteria considerably weaker. Human health safety for primary or secondary contact recreation is **not** being protected by the Arkansas criteria for *E. coli*.

**Table 2.** *Arkansas water quality standards for Escherichia coli:*

<i>Escherichia coli</i>		STANDARD	SUPPORT	NON-SUPPORT
PRIMARY CONTACT	ERW, ESW, and NSW Waters	GM 126 col/100 mL*	≤ standard	> standard
	Lakes, Reservoirs	298 col/100 mL (May-Sept)	≤ 25% exceedance	>25% exceedance
	All other waters	410 col/100 mL (May-Sept)	≤ 25% exceedance	>25% exceedance
SECONDARY CONTACT	ERW, ESW, and NSW Waters	GM 630 col/100 mL*	≤ standard	> standard
	Lakes, Reservoirs	1490 col/100 mL (anytime)	≤ 25% exceedance	>25% exceedance
	All other waters	2050 col/100 mL (anytime)	≤ 25% exceedance	>25% exceedance

ERW: Extraordinary Resource Water NSW: Natural and Scenic Waterway ESW: Ecologically Sensitive Water

\*Geometric mean can be calculated for any 30-day period within a season (primary season May 1 through September 30; secondary season October 1 through April 30).

**Table 3.** *Two sets of threshold criteria recommended by the U.S. EPA (2012) for Escherichia coli fecal bacteria to protect human health safety in waters used for primary contact recreation. (Note: gm (GM) = geometric mean; STV = statistical threshold value.) The waterbody GM should not be greater than the selected GM magnitude in any 30-day interval; and there should be no greater than a 10% excursion frequency of the selected STV magnitude in the same 30-day interval.*

Criteria Elements	Recommendation 1 Estimated Illness Rate 36 / 1000		Recommendation 2 Estimated Illness Rate 32 / 1000	
	gm (cfu / 100 mL)	STV (cfu / 100 mL)	gm (cfu / 100 mL)	STV (cfu / 100 mL)
<i>Escherichia coli</i> (fresh)	126	410	100	320

- Arkansas has no numeric nutrient criteria. The Report describes an inadequate approach for assessing nutrient-related impairment, which biases against finding nutrient-related impairment and fails to protect Arkansas surface waters from loss of designated uses due to nutrient pollution.

Nutrient pollution is among the most important sources of impairment to the nation’s waters (National Research Council 2000). In addition to impairment of Arkansas surface waters by nutrient and associated pollutants, the state adds about 7% of the total nitrogen and 10% of the total phosphorus to the Gulf of Mexico via the Mississippi River and, thus, is a significant

contributor to the nutrient pollution that feeds the major Dead Zone at the river mouth (Barvenik et al. 2009). The U.S EPA (2000a,b) mandated states to adopt ambient nutrient criteria for total phosphorus (TP) and total nitrogen (TN) that EPA had developed, or to develop their own scientifically defensible numerical criteria for nutrients that protect the designated uses of waterways.

ADEQ has included various waterbodies impaired by nutrient pollution on its 303(d) list. The Report (p.25) accurately describes numeric criteria as values that provide a quantitative basis for evaluating designated use support and for managing point and nonpoint loads to surface waters. Unfortunately, ADEQ has not followed through on this rhetoric regarding numeric nutrient criteria. A decade after U.S. EPA's mandate, the U.S. EPA/Office of Inspector General (Barvenik 2009) expressed concerns about the progress made by Arkansas to protect its waters from nutrient pollution. More than 15 years later, Arkansas still has not developed any numeric nutrient [N and P] criteria. Instead, ADEQ has developed numeric criteria for what are generally regarded as direct (chlorophyll *a*, indicator of suspended microalgal biomass) or indirect response variables (DO concentrations, diel DO changes or DO flux [change] over a 24-hour period) to nutrient enrichment. Moreover, the numeric criteria for the response variables are based on a sampling approach that is inadequate to reliably assess whether waters are nutrient-impaired.

As part of its Nutrient Criteria Development Plan, thus far ADEQ (2005) has designed one set of *lake-specific* water quality criteria (= specific for one impoundment, the Beaver Reservoir). *Although these water quality criteria were called "numeric nutrient criteria" by ADEQ (Report, p.22), they are not.* Nitrogen and phosphorus are the two major nutrients that, when over-supplied, cause noxious algal outbreaks (Wetzel 2001, Burkholder 2009). Chlorophyll *a* is not a nutrient; it is an algal pigment. Turbidity is not a nutrient; it is a measure of water-column 'cloudiness.' The Report describes the same approach, lacking entirely in numeric nutrient criteria, being planned for application to other significant impoundments in the state as of a decade ago (ADEQ 2006).

- a) *The ADEQ protocol design sets thresholds for excess TN and TP at a much higher, much less protective level than would be set from use of U.S. EPA's recommended protocols.*

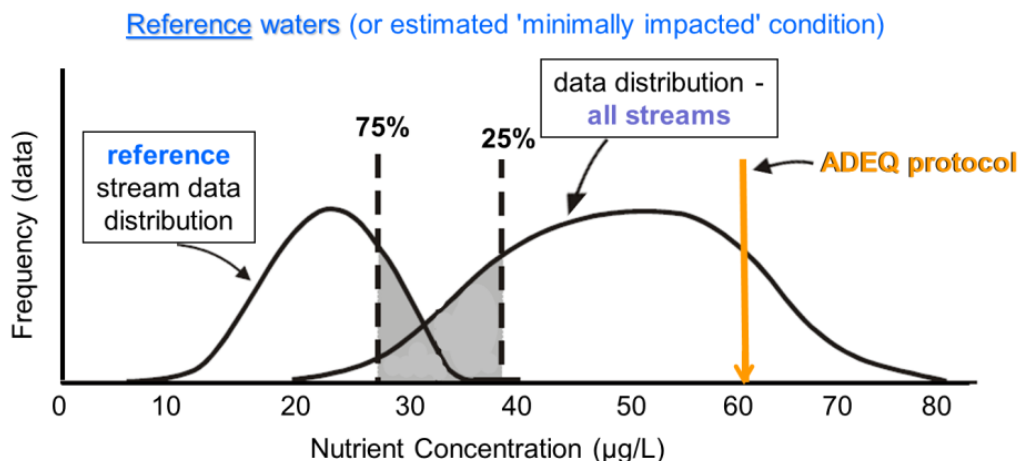
The Report (p.46) states,

Because nutrient water column concentrations do not always correlate directly with stream impairments, impairments will be assessed by a combination of factors such as water clarity, periphyton or phytoplankton production, dissolved oxygen values, dissolved oxygen saturation, diurnal [diel] dissolved oxygen fluctuations, pH values, aquatic-life community structure and possibly others. However, when **excess nutrients** [emphasis added] result in an impairment, based upon Department assessment methodology, by any Arkansas established numeric water quality standard, the waterbody will be determined to be impaired by nutrients.

ADEQ has established a protocol which sets levels of excess TN and TP. Its protocol sets these thresholds much higher (that is, the thresholds are much less protective) than the procedure

recommended by U.S. EPA's (2000a,b). The U.S. EPA (200a,b) recommends that if true reference (pristine) sites are available for a given ecoregion within a state, the state should use the 75<sup>th</sup> percentile of data collected in the past ~decade from the reference sites as the threshold numeric nutrient (TN, TP) criteria. If true reference waters can no longer be found in the ecoregion, the U.S. EPA recommends that to prevent deviation from "minimally impacted" water quality, the state should use the 25<sup>th</sup> percentile of all data, that is, data available (past ~decade) from all streams in the ecoregion within the state in setting numeric nutrient (TN, TP) criteria:

#### U.S. EPA recommendations versus ADEQ



**Reference - 75th percentile of all data for reference streams;** approximates "minimally impacted" conditions; also somewhat similar to (although lower than) the **25th percentile of all streams data** - recommended for use when reference streams are not available; but if in a highly urban or agricultural area, use 5th to 15th percentile.

**75<sup>th</sup> percentile of all streams data – ADEQ protocol, not protective; much higher nutrient concentrations are deemed “acceptable.”**

**Figure 3.** Comparison of U.S. EPA-recommended protocols for setting numeric thresholds for nutrients (TN, TP – U.S. EPA 2000a,b), versus ADEQ's in the Report.

Thus, scrutiny of ADEQ's "Assessment Methodology for Nutrients" shows that, rather than following U.S. EPA's (2000a,b) protective recommendations, ADEQ designed a protocol for wadeable streams and rivers which begins by assuming that **much higher** TN and TP concentrations are "acceptable:" Moreover, if these high concentrations are not exceeded, then ADEQ simply assumes that there is no nutrient-related impairment. If the high concentrations ADEQ has selected are exceeded, however, the agency does not evaluate the waterbody as impaired. Rather, ADEQ follows a set of steps that are biased against finding impairment.

- b) *The ADEQ protocol flow chart for evaluating whether wadeable streams within a given ecoregion have nutrient-related impairment requires “paired data” that are not paired.*

ADEQ defines paired data/collections as “combined physical, chemical, and biological collections within the same calendar year and/or season. This definition is scientifically indefensible and makes no sense. The nutrient and/or DO, diel DO flux, DO saturation, and pH data can be taken *on the same date* or *after* the biological data are taken, which fails to account for known lag effects of nutrient pollution (Burkholder and Glibert 2013, and references therein). Far from “pairing” data, ADEQ’s protocol allows the “cart to proceed before the horse” – water quality data can be taken *after* biological data. Alternatively, the “paired” data can be collected within *the same year*. Thus, macroinvertebrates could be collected in January. Nutrients could be collected in August. There is no science-based rationale in support of the premise that nutrient concentrations influenced the macroinvertebrates (or vice versa). Rather than enabling ADEQ to determine whether biological effects are linked to nutrients, such an approach would easily, completely miss impairment from nutrient pollution.

- c) *The ADEQ protocol includes arbitrary stipulations that do not appear to have basis in science.*

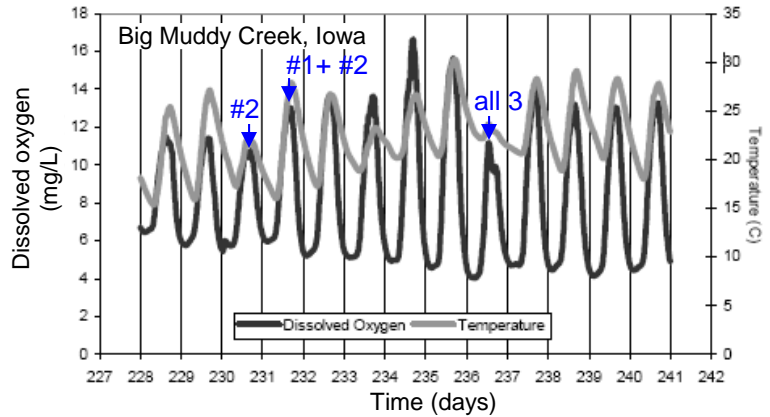
Not only one but, rather, both of the 3-day continuous monitoring datasets must have at least 2 of the following 4 parameters (referred to as “translators”) in exceedance, defined as:

Diel DO flux greater than 3 mg/L,  
DO percent saturation greater than 125% for 4 or more consecutive hours,  
DO below the applicable standard for 4 or more consecutive hours, and  
pH less than 6 or greater than 9.

The Report should explain the scientific basis as to why defined DO supersaturation above 125% and DO “sags” below the applicable standards must persist for “4 or more consecutive hours.” The protocol also reflects no consideration by its designers of the following facts, well accepted in science:

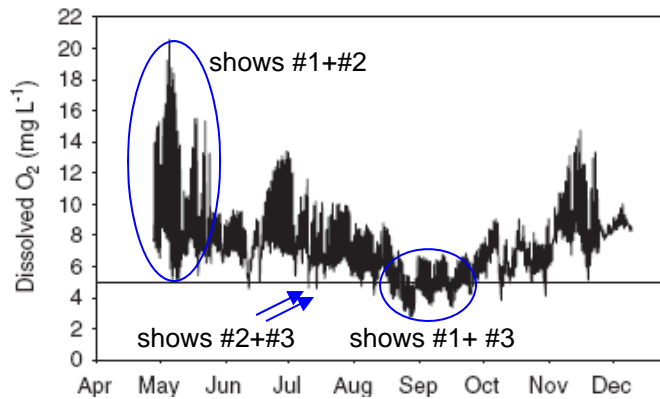
**\*\*** *Many surface waters that are impaired from nutrient pollution show one, but not two or more, of these “translator” violations within a given 3-day period* – Depending on many characteristics such as temperature, flow, animal abundances, the presence of actively growing versus senescent or decomposing algal biomass, and variability in organic pollution impacts, the same stream can show any combination of these characteristics, including only one of them. The pattern can quickly change within a matter of 1-2 days depending on weather conditions. The following examples of diel DO curves are from streams known to be impaired by nutrient pollution. They illustrate that it would not be scientifically sound to require wadeable streams to show two or more of these characteristics within a 3-day period in order for the stream to be evaluated as in need of protection from nutrient pollution.

**First example:** A stream draining agricultural lands, with diel data taken during late summer (late July to mid-September): The streams in this study had high mean nutrient concentrations (4.7 mg TN/L and 246 µg TP/L). Depending on the period selected, diel curves for this stream show only 1 characteristic (#1 = diel change greater than 3 mg DO/L), characteristics #1 and #2 (#2 = supersaturation at greater than 125%), characteristics #1, #2, and #3 (low DO) during this late summer period. The fourth characteristic, pH, was not less than 6 or greater than 9 (range, 7.8 to 8.9).



**Figure 4.** Example 1- From Huggins and Anderson (2005).

**Second example:** A stream draining croplands, with diel data taken throughout the growing season. This stream is highly nutrient-enriched from agricultural sources. Yet, depending upon the time of year, and even within the same season (June through late August), diel DO curves varied greatly. I have indicated dates/periods when two of the four “translators” would have been exceeded. However, there clearly are various three-day periods shown wherein none of the “translators” were exceeded. The stream was hypoxic for much of August-September, conditions that would be expected to stress or kill beneficial aquatic life. The authors of this study described this stream as clearly impacted by nutrient pollution. Analysis of macro-invertebrate communities in a companion study (Heatherly et al. 2007) indicated that the biota of this stream were being adversely affected by nutrient pollution. Yet, this stream would not be evaluated as requiring protection from nutrient pollution if a requirement was imposed that at least two “translators” had to be exceeded within two 3-day periods, depending on the periods selected. Note that pH data were not given in Moore et al. (2006), but Heatherly et al. (2007) did not report pH below 6 or above 9.



**Figure 5.** Example 2 - Continuous DO concentrations in an open-canopy agricultural stream from late April through early December (horizontal line indicates the 5 mg/L Illinois standard at the time of the study). From Morgan et al. (2006).

**\*\* Impairment from nutrient pollution can occur without manifestation of these “translator” exceedances – Examples include nitrate and ammonia toxicity to aquatic life, which can occur in**

response to nutrient pollution when surface waters are oxygen-replete. Toxic levels of these forms of inorganic nitrogen ( $N_i$ ) cause physiological stress, impaired reproduction, and death of sensitive aquatic species and life history stages. Ammonia and nitrate are considered separately below, but it should be noted that these forms of  $N_i$  have been shown to act synergistically to adversely affect aquatic life (e.g. Berenzen et al. 2001, Beketov 2004).

As reviewed in Camargo and Alonso (2006), unionized *ammonia* is highly toxic especially to fish, and is thought to act through one or more of the following mechanisms: Damage to gill epithelium, causing asphyxiation; stimulation of glycolysis and suppression of the Krebs cycle, resulting in acidosis and reduced capability of the blood to carry oxygen; uncoupling of oxidative phosphorylation, inhibiting ATP production and depleting ATP in the basilar region of the brain; disrupting blood vessels and osmoregulation, impairing liver and kidney functions; and suppressing the immune system, increasing susceptibility to disease. Ionized ammonia (*ammonium*,  $NH_4^+$  ions) can exacerbate  $NH_3$  toxicity by reducing internal sodium ion concentrations. Environmental conditions such as low DO can *increase* fish susceptibility to ammonia toxicity, but ammonia toxicity can also occur when oxygen supplies for fish are plentiful (Camargo and Alonso 2006). Freshwater invertebrates such as molluscs and planarians appear to be highly sensitive to  $NH_3$  toxicity as well, and have sustained adverse impacts from chronic exposures to as little as 50  $\mu g NH_3/L$ .

ADEQ includes tests for ammonia toxicity (Report, Section 6.12), but the concentrations indicated as “acceptable” are much higher than those given in the *Aquatic Life Ambient Water Quality Criteria for Ammonia in Freshwater* (U.S. EPA 2013). The U.S. EPA (2013) recommended criteria are based on sensitive freshwater bivalve mollusc species. According to the U.S. Fish and Wildlife Service (see <http://www.fws.gov/arkansas-es/docs/ESDay/Photographs%20of%20Endangered%20Species%20in%20Arkansas.pdf>),

Freshwater mussels are the second most endangered group of animals in North America, second only to freshwater snails. They are indicator species of the health of our streams and rivers. Arkansas has the most species of native freshwater mussels of any state west of the Mississippi River (83 species). They also are the most endangered group of animals in Arkansas....The greatest threats facing Arkansas' mussels include...chemical pollution....

Thus, it would seem that ADEQ should have adopted the U.S. EPA (2013) criteria to protect these endangered fauna of Arkansas' wadeable streams. Yet, the Report does not mention the U.S. EPA criteria.

The Report also does not mention *nitrate toxicity to aquatic life* in the state's wadeable streams, as related to nutrient impairment. The main mode of action of *nitrate*, especially in fish and crayfish, is conversion of oxygen-carrying hemoglobin or hemocyanin pigments into methemoglobin or methemocyanin forms that can no longer carry oxygen, leading to hypoxia and death (Camargo and Alonso 2006, and references therein). Nitrate can interfere with steroid hormone synthesis, affect sperm motility and viability, affect fecundity, and can be toxic to embryos (Edwards et al. 2004). It can also decrease immune response, act as an endocrine disruptor, and induce hematological and biochemical changes in aquatic life (Guillette and Edwards 2005, Edwards 2005). Nitrate may also



adversely affect many metabolic processes by acting as an endocrine disruptor in fishes and reptiles (Hrubec et al. 2002, Guillette and Edwards 2005, Edwards 2005). Within body fluids, nitrate can be converted to nitrite, or can accumulate via hepatic detoxification of nitrite (Edwards et al. 2004).

Experiments have shown that nitrate concentrations well below 10 mg/L, the National Primary Drinking Water Regulation, or primary standard for nitrate in drinking water (see <https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Inorganic>), can adversely affect freshwater invertebrates, fish, and amphibians (Camargo et al. 2005). Certain aquatic invertebrate and fish species have been found to be especially sensitive to nitrate toxicity. As examples, chronic nitrate toxicity for freshwater invertebrates can occur at values as low as 0.23 mg NO<sub>3</sub>-N/L; lowest chronic toxicity levels for adult freshwater invertebrates were 2.8-4.4 mg/L for two species of amphipods (Camargo et al. 2005). Early instar caddisfly larvae sustained adverse effects from chronic toxicity at 1.4-2.4 mg NO<sub>3</sub>-N/L (Camargo and Ward 1995).

The 303(d) list given in the Report includes several cases of stream impairment due to nitrate. Since the Report mentions nothing about criteria for nitrate aimed at protecting aquatic life, apparently these cases are in violation of the 10 mg/L standard, which is much too high to be protective of aquatic ecosystems.

- d)** *The protocol for continuous monitoring data for assessing “nutrient-related impairment” of wadeable streams will easily miss or underestimate the DO “translators.”*

The ADEQ protocol requires only two 3-day periods within the entire May-October growing season, at times when temperatures are at 22°C or higher. Such limited continuous monitoring data will easily miss or underestimate the “translators” DO flux, low DO concentrations, and DO supersaturation above 125%. Protection of Arkansas waters from nutrient pollution based on these DO “translators” will critically depend upon adequate monitoring in the summer season, including at least several days of data taken before and after precipitation events, as well as during droughts. As examples illustrating the importance of adequate sampling, see Figures 4 and 5, and accompanying descriptions and references in these Comments.

- e)** *The numeric criteria (chlorophyll *a*, turbidity) set for the upper end of Beaver Lake are poorly conceived and do not protect this reservoir from impairment due to nutrient pollution.*

Thus far, ADEQ has designated site-specific chlorophyll *a* concentration and turbidity numeric criteria for the *upper portion only*, of *only one reservoir*, Beaver Lake. The chlorophyll *a* concentration is used as an indicator of algal biomass (Wetzel 2001). While chlorophyll *a* is considered a “response variable” to nutrient pollution, turbidity, or water-column transparency, is only considered to be related to nutrient pollution if the materials causing increased “cloudiness” are algae. Secchi depth transparency and other measures of turbidity are **not** strongly related to nutrient concentrations if the main source of the turbidity is abiotic, such as suspended sediment particles (Wetzel 2001). Thus, the chlorophyll *a* concentration can be related, at least, to nutrient

concentrations, but turbidity is often not well related to nutrient concentrations, especially in river and reservoir systems which have appreciable abiotic (non-algal) turbidity and where much of the TN occurs as highly soluble nitrate.

The upper portion of a reservoir generally is the area with the highest nutrient concentrations, contributed by the incoming river, but also the highest turbidity and the highest flow relative to the middle and lower (by the dam) reservoir waters (Wetzel 2001). The high turbidity and high flow in the upper reservoir depress algal growth, thereby minimizing algal response to nutrient supplies. The algae cannot fully respond to the high nutrient supplies because the high turbidity restricts the light they need for photosynthesis, and the high flow moves them out of the area into the middle reservoir too quickly; they can consume the nutrients, but they do not have the light they need or the time to grow, that is, to translate that uptake into more biomass. Therefore, the upper end of a reservoir usually has much lower algal biomass than the middle and lower end. As the algae are moved through the reservoir by the slowing current, they are able to use the nutrients they consumed in the upper end of the reservoir and grow, making much more biomass. The water clears during this transport, and is usually much clearer at the lower end of the reservoir; and the water movement is much slower at the lower end of the reservoir above the dam, allowing good light for growth so that noxious algal blooms commonly occur in the lower reservoir.

Thus, high incoming nutrient supplies usually coincide with high flow, high turbidity, and relatively low algal biomass (indicated by relatively low chlorophyll *a* concentrations) at the upper end of a reservoir. *High incoming nutrient supplies in the upper end of a reservoir also commonly lead to high algal biomass at the lower end of the reservoir.*

ADEQ developed a numeric criterion for chlorophyll *a* in the upper end of the Beaver Lake reservoir as 8 µg/L (depth, 1 meter). An average (mean) chlorophyll *a* concentration of 8 µg/L indicates conditions that are *midway between moderately nutrient-enriched* (which limnologists call mesotrophic, for example, waters that are nutrient-enriched enough to develop medium-sized algal blooms) *and highly nutrient-enriched* (referred to as eutrophic) (Wetzel 2001 – see Table 4 below). Thus, ADEQ deemed it acceptable for even the upper end of the reservoir, which should be low in algal biomass, to have moderate algal biomass concentrations.

**Table 4.** Average (mean, or arithmetic mean, AM) concentrations in lakes and reservoirs ranging from nutrient-poor to nutrient-rich. From Wetzel (2001).

General level of productivity	Suspended microalgal chl <i>a</i>
oligotrophic (pristine, nutrient-poor)	average 2 µg/L
mesotrophic (moderately productive)	average 5 µg/L
eutrophic (nutrient-rich, highly productive)	average 14 µg/L

Note, however, that Table 4 refers to **average (mean, or arithmetic mean, AM)** chlorophyll *a* concentrations. ADEQ imposed another stipulation to make this numeric criterion less protective

even for the upper end which should have the lowest algal biomass in the entire reservoir: Rather than setting a numeric criterion for chlorophyll *a* that is an average or mean for the May-October growing season, ADEQ elected to make this criterion a **geometric mean (GM)**. *GMs are always lower than AMs* unless all of the data for a given parameter are the exact same number, which is highly unlikely.

Rather than setting a numeric criterion of 8 µg chlorophyll *a*/L as an AM concentration that is acceptable over the growing season (May-October), ADEQ designed a less protective criterion by stipulating that it must be a GM. The following examples illustrate the difference between a GM and an AM. Numbers indicate the chlorophyll *a* concentration in micrograms per liter (µg/L), rounded to the nearest integer:

	<u>Year 1</u>	<u>Year 4</u>			
Samples:	3, 4, 5	14, 15, 30	GM: 8	AM: 12	median: 10
Samples:	17, 22, 14	4, 6, 2	GM: 8	AM: 11	median: 10
Samples:	4, 3, 5	20, 14, 15	GM: 8	AM: 12	median: 13

First example above: Low concentrations occurred when the sparse number of samples (n = 3) were taken in the first year; but the (again, sparse) sampling in the second (4<sup>th</sup>) year caught a developing noxious algal bloom. There is no way to know whether the chlorophyll *a* concentration continued to rise because additional samples were not taken, despite the fact that this level of chlorophyll would have caused obvious water discoloration. There is no way to assess the bloom duration or impacts.

Second example: A substantial algal bloom (perhaps subsiding) was detected by the sparse sampling during the first year. There is no way to assess the bloom duration or impacts. The sparse sampling during the second (4<sup>th</sup>) year detected had low algal biomass.

Third example: Low algal biomass was measured by the sparse sampling in the first year; but the sparse sampling in the second year detected a major bloom that may have been occurring for some time; there is no way to assess the bloom duration or impacts.

The central question should be, *What is the best approach, with very small sample numbers such as are relied upon by ADEQ, to estimate the “true” average condition?* When sample sizes are small and the data are used to represent a long period (e.g., several months, such as the May-October period), statisticians recommend use of **medians** rather than geometric means or arithmetic means. (It is worthy of mention that the best-known use of GMs, for fecal bacteria, are based on 4-5 samples *per month*, a much smaller time period.) Note that in 2 of the 3 examples above, the median is closest to the AM; in the other example, the median is equi-distant between the GM and the AM. Overall, these examples indicate that the AM depicts a “truer” mean than the GM with small sample sizes which ostensibly are taken to represent relatively long periods (here, the small sample size of 6 supposedly representing 5 months, or the entire growing season). Also note that *even the medians are higher than the GMs in all three examples.*

Small sample sizes around 5-6 have been found to have much larger uncertainty in estimating a true GM than larger sample sizes (Parkhurst 1998, Sokal and Rolff 2012). Because the “n” relied upon by ADEQ for assessing nutrient-related impairment is so small, it would be better to base compliance on medians than on GMs. Both the GM and the median are less sensitive to outliers than the mean. The advantage of the median is that, for small datasets, it can be a better (= more reliable, more realistic) measure of central tendency in data that are not normally distributed (Sokal and Rolff 2012) – and water quality (nutrient, chlorophyll) data are often *not* normally distributed (Burkholder et al. 2006, Sokal and Rolff 2012).

These realistic examples illustrate that in general, GMs substantially underestimate the “true” average condition as indicated by medians. Parkhurst (1998) wrote,

Concentrations of chemical substances and microorganisms are often averaged for scientific and regulatory purposes. Geometric means are sometimes used for these purposes, but they are biased low and do not represent components of mass balances properly. They should be abandoned in favor of arithmetic means, unless they are clearly shown to be preferable for specific applications. Arithmetic means are unbiased, easier to calculate and understand, scientifically more meaningful (at least for concentration data), and more protective of public health.

Regarding use of turbidity as a “nutrient criterion” or as an indicator of meeting a drinking water use, the Secchi depth transparency numeric criterion is an annual average (!). As an annual average, the data will provide no science-based way to evaluate whether the upper lake is meeting its designated use for drinking water. Regarding any utility of an “annual average Secchi depth transparency”: If the turbidity in the upper lake was all related to algae, and if the measurements coincided with chlorophyll *a* measurements, and if the measurements were restricted to the growing season, then Secchi depth transparency might be useful in providing some indirect information about nutrient pollution (see Wetzel 2001). However, the turbidity in the upper lake is caused both by algae and suspended solids coming in from the river. Annual average Secchi depth transparency data provide no meaningful information about nutrient impairment to the upper lake, either.

- f) *The Report provides no explanation as to why ADEQ has designed unbalanced listing versus delisting criteria for upper Beaver Lake.*

Although the upper end of Beaver Lake was described as having “numeric nutrient criteria” (chlorophyll *a*, turbidity) to protect it from nutrient-related impairment, and although the Listing and Delisting Methodologies are given under the section heading, “**6.9 Nutrients – Assessment Methodology for Nutrients**” (Report, p.46), “suddenly” readers learn on p.49 that the only issue of concern for ADEQ regarding upper Beaver Lake will be whether it supports its ***drinking water*** designated use – not whether it is impaired from algal blooms (indicated by high chlorophyll *a*) or other impacts that are at least related to nutrient pollution. Moreover, *nothing whatsoever is mentioned about nitrate, which is actually the only nutrient that **has** a drinking water standard.*

The Listing Methodology states that there must be **3 or more exceedances** of the chlorophyll *a* criteria (see comment #8d above) within the 5-year period of record; and (? or? – not clarified) there must be 3 or more exceedances of the Secchi [depth] transparency criteria within the 5 years.

versus

Delisting will occur when there are **2 or fewer exceedances** of the chlorophyll *a* criteria **and 2 or fewer exceedances of Secchi depth** transparency within a 5-year period.

Scrutiny of the Report yielded no information about the actual number of chlorophyll samples required per growing season in upper Beaver Lake. The site-specific water quality criteria development document (FTN Associates 2008, p.9-21) recommended monthly sampling because they felt that it would be “consistent with the current ADEQ monitoring program, and it provides sufficient information for estimating growing season chlorophyll....” However, for about 20 yr ADEQ has monitored lakes only in one of every five years (Report, p.22). Regardless, a difference of as little as only ONE chlorophyll sample and ONE turbidity sample (Secchi depth transparency) between listing and delisting seems illogical and suggests that there is poor protection of upper Beaver Lake from impairment due to high chlorophyll *a* as an indicator of noxious algal blooms.

### ***Recommendations***

The following recommendations are offered toward the goal of strengthening the protocols for assessing impaired surface waters in Arkansas, and strengthening protection of the surface water resources in the state:

- Clear time frames should be stipulated for Integrated Reporting Categories 4(b), Category 5-Medium, and Category 5-Low, so that cleanup of known-impaired waters within these categories is not “indefinitely postponed.”
- Monthly data frequency should be required for Tiers III and IV data. Bimonthly or quarterly data are adequate for screening (Tiers I and II), but not for assessment of average conditions and attainment of designated uses.
- The “two seasons” requirement for macroinvertebrate sampling should be clarified to stipulate that the seasons should be selected to avoid temperature extremes. At least two years of sampling should be required for assessment data in order to at least partly account for inter-annual variation.
- The Aquatic Life Designated Use Listing Protocol should be altered so that it accurately evaluates Partially Supporting macroinvertebrate communities, rather than “suddenly transforming” them into Fully Supporting communities as accomplished by the present protocol.
- The Aquatic Life Designated Use Listing Protocol should be altered so that it accurately evaluates loss of fish species diversity, loss of sensitive species, and an increase in pollution-tolerant fish species as “acceptable” (supporting).

- ADEQ should assess surface waters throughout the state for historic data where available and present DO conditions *throughout* the water column. The reservoir DO criterion should be altered to include protection of benthic aquatic life from low DO stress during the critical season in waterbodies where bottom-water hypoxia/anoxia have been or are being exacerbated by human-related activities.
- Throughout the state, intermittent streams with enduring (perennial) pools and small perennial headwater streams draining watersheds less than 10 square miles in areal extent should have a critical-season DO criterion that protects them from hypoxia/anoxia.
- The Arkansas water quality criteria for *Escherichia coli* fecal bacteria should be significantly reduced in order to protect human health safety. The criteria should be altered to follow the U.S. EPA (2012) recommendation, and compliance should also follow U.S. EPA (2012).
- Arkansas should develop numeric **nutrient** criteria . At present the state has not developed any **phosphorus and nitrogen numeric criteria**. Criteria for both nutrients are needed, rather than criteria for chlorophyll *a* and turbidity which are **not** nutrients. In the Report these criteria are erroneously called “numeric nutrient criteria.” Adding yet more confusion, the chlorophyll *a* and turbidity criteria are not being used to assess nutrient conditions, related to aquatic life use; rather, they are being used to assess whether upper Beaver Lake is meeting its designated use for drinking water. Arkansas should look to states such as Minnesota and Wisconsin as examples of numeric nutrient criteria.
- The ADEQ protocol for excess TN and TP in wadeable Arkansas streams should be set at the 25<sup>th</sup> percentile of all streams data within a given ecoregion following U.S. EPA recommendations, rather than at the much-less-protective 75<sup>th</sup> percentile.
- The ADEQ protocol for evaluating whether wadeable streams have nutrient-related impairment should use data for water quality that, when paired with biological data, include a science-based lag period so that a link between poor water quality and impaired biota can actually be assessed. Apparently arbitrary stipulations should be clarified and clearly science-based. The protocol should also be substantially altered to require only one, rather than two or more, of the four translators in violation; and to include criteria to protect aquatic life from excessive nitrate and ammonia toxicity, which can cause adverse impacts without manifestation of any of the “translators.” Continuous monitoring data for the DO “translators” should be increased to include several days of data taken before and after precipitation events, and data taken during droughts.
- The numeric criteria (chlorophyll *a*, turbidity) set for the upper end of Beaver Lake should be redesigned so that they are science-based and protective rather than reactive. Toward that goal, median chlorophyll *a* concentrations should be used rather than geometric means. The chlorophyll *a* criterion of 8 µg/L for the upper, most turbid end of the reservoir should be lowered so that the middle and lower reservoir are afforded more protection from excessive algal blooms. Use of annual average Secchi depth as an indicator of nutrient-related

impairment, or as an indicator of the lake meeting its designated use for drinking water, should be abandoned because it does not provide meaningful information for either.

- The number of chlorophyll *a* samples required per growing season and per five-year period to assess whether upper Beaver Lake meets its designated uses requires clarification.
- The rationale for the imbalance between Listing and Delisting Methodologies for upper Beaver Lake requires clarification so that readers can assess whether the methodologies are science-based, and whether the protocol provides meaningful protection for this surface waterbody.

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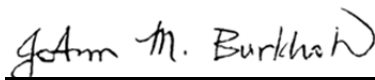
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JoAnn M. Burkholder, Ph.D.

# Curriculum Vitae

## JoAnn Burkholder

Professor and Director, NCSU Center for Applied Aquatic Ecology,  
Department of Applied Ecology /  
Jointly Appointed in the Department of Plant and Microbial Biology;  
Affiliate Professor, Department of Marine, Earth and Atmospheric Sciences

### Contact Information

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### Education

Undergraduate:	Iowa State University	Zoology	B.Sc., 1975
Graduate:	University of Rhode Island	Aquatic Botany	M.Sc., 1981
	Michigan State University	Botanical Limnology	Ph.D., 1986

### Research Interests

Algal nutritional physiology and ecology, spanning the salinity gradient from freshwater to estuarine and marine species; and chronic effects of eutrophication (nutrient over-enrichment and associated pollutants) on aquatic ecosystems

### Professional Experience

2013 - present	Director, CAAE, Department of Applied Ecology, NCSU
2013 - present	Professor, Department of Applied Ecology; jointly appointed to the Department of Plant & Microbial Biology (formerly the Department of Plant Biology), NCSU
1999 - 2012	Director, CAAE, Department of Plant Biology, NCSU
1998 - 2012	Professor, Department of Plant Biology (formerly the Department of Botany), NCSU
1993 - 1997	Associate Professor, Department of Botany, NCSU
1993 - present	Affiliate Professor, Department of Marine, Earth and Atmospheric Sciences (MEAS), NCSU
1986 - 1992	Assistant Professor, Department of Botany, NCSU
1982 - 1986	Graduate Research Assistant, Michigan State University (W.K. Kellogg Biological Station), Hickory Corners, MI
1981 (fall)	Instructor, <i>Introductory Chemistry</i> (for science majors), Quinebaug Valley Community College, Danielson, CT
1979 - 1980	Instructor of <i>Marine Botany</i> , summers, St. Georges College Prep. School, Newport, RI
1978 - 1981	Graduate Research Assistant and Graduate Teaching Assistant, Department of Botany, University of Rhode Island, Kingston, RI
1976 - 1977	Environmental Scientist, EcolSciences, Inc., Rockaway, NJ
1974 - 1975	Undergraduate Research Assistant, Limnology Laboratory, Department of Zoology, Iowa State University, Ames, IA

### Awards and Distinctions

2009	Borlaug Joint Award for Service to the Environment and Society, College of Agriculture and Life Sciences/ College of Natural Resources, NCSU
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- 2008 William Neal Reynolds Distinguished Professor, College of Agriculture and Life Sciences, NCSU, for excellence in research
- 2008 J. Compton River Achievement Award, River Network, lifetime achievement for leadership in research to advance water quality protection
- 2007 Darbaker Prize, Botanical Society of America, for excellence in research
- 2004 Fellow, American Association for the Advancement of Science (AAAS)
- 2003 Honorary Doctorate, Knox College, Galesburg, IL
- 2003 Provasoli Award, best paper of 2002, *Journal of Phycology*
- 2001 Honorary Doctorate, Southampton College - Long Island University
- 2000 Fellow, Aldo Leopold Leadership Program, Ecological Society of America
- 1999 Hutner Award, Society of Protozoologists, for excellence in microalgal research
- 1998 Scientific Freedom and Responsibility Award, AAAS
- 1998 Distinguished Service in Environmental Education Award, Environmental Educators of North Carolina
- 1998 Distinguished Scholarly Achievement Award, NCSU Honors Convocation
- 1998 Conservationist of the Year Award, National Wildlife Federation
- 1998 Conservationist of the Year Award, Governor of North Carolina and the North Carolina Wildlife Federation
- 1998 Jack Bayless Award – outstanding presentation of the year, South Carolina Fishery Workers Association, and the North and South Carolina chapters of the American Fisheries Society
- 1997 Admiral of the Chesapeake Award, Federal and State Leadership Summit, Washington, DC
- 1997 Outstanding Achievement Award, Society of Business and Professional Women of North Carolina
- 1997-2000 Pew Fellow in Marine Conservation, the Pew Foundation
- 1994 Outstanding Research Award, NCSU Alumni Association

### Honors to the NCSU CAAE

- 2013 The CAAE was recognized as the reason why NCSU placed 31<sup>st</sup> among the top 50 “Colleges Saving the World” (<http://www.onlinecollegesdatabase.org/50-colleges-saving-the-planet>).
- 2012 The CAAE received the highest evaluation possible (Excellent) by an outside Peer Review Panel that reviewed in detail the Center’s performance over its entire span of operation. The panel was organized by the NCSU College of Agriculture and Life Sciences, as required by the UNC Board of Governors.

### Other Honors

- 2013 Invited presentation on Harmful Algae - Capital Hill Briefing, representing the Coastal and Estuarine Research Federation
- 2007 Theodore L. Jahn and Eugene C. Bovee Award, International Society of Protozoologists, for best graduate student research paper, to doctoral candidate Hayley Skelton (coauthors of the paper, Burkholder and Parrow)
- 2001 Elected member, Alumni Hall of Fame, Rock Valley College, Rockford, Illinois
- 2001 Convocation speaker, Appalachian State University
- 2001 Convocation speaker, Southampton College - Long Island University
- 1998 Special recognition for excellence in research, Phi Kappa Phi
- 1998 Invited testimony, Congressional Hearing on the Value of Estuaries, US Senate, Senate Environment and Public Works Committee
- 1998 Invited testimony, Congressional Hearing on Harmful Algal Blooms, US Senate, Committee on Commerce, Science and Transportation

1997	Invited testimony, Congressional Hearing on Fisheries Conservation, Wildlife and Oceans, US House of Representatives – Committee on Resources
1997	Invited testimony, Congressional Hearing on Harmful Algae and Human Health, US House of Representatives – Committee on Government Reform and Oversight
1997-1999	Science Advisor, Governor’s Commission on <i>Pfiesteria</i> , Maryland
1993-1994	Member, North Carolina Coastal Futures Committee (governor-appointed)
1993-1995	Member, Board of Directors, Partnership for the Sounds (directive, environmental education for eastern North Carolina)
1992-1997	Member-at-large, North Carolina Marine Fisheries Commission (governor-appointed)
1985	Elected member, Phi Kappa Phi, Michigan State University
1984-1986	Graduate fellow, Department of Botany and Plant Pathology, Michigan State University

## **Selected Research Accomplishments**

(with thanks to my graduate students, postdoctoral research associates and other research associates, and collaborators)

### ***Freshwater Ecosystems***

- First to maintain automated platform stations with depth profiling capability for advanced research and monitoring of North Carolina reservoirs; the real-time data from these stations is also helping to safeguard drinking water supplies depended upon by ~750,000 people.
- Experimentally quantified interactions between nutrient and sediment loadings in controlling noxious algal blooms in turbid reservoirs.
- First to document widespread occurrence, at low levels, of cyanotoxins in major potable water supplies in North Carolina.
- Documented novel nutritional and physical adaptations of a cryptic group of dinoflagellates in reservoirs affected by episodic suspended sediment loading.

### ***Estuarine and Marine Ecosystems***

- Discovered that water-column nitrate enrichment from sewage and other sources inhibits *Zostera marina*, the dominant seagrass of north temperate U.S. waters, as a direct physiological effect.
- Co-discovered the toxic dinoflagellates, *Pfiesteria piscicida* and *Pfiesteria shumwayae*, as causative agents of major estuarine fish kills; this research also led to colleagues’ discovery of a group of *Pfiesteria* toxins new to science.
- First to design and maintain a series of automated platform stations for advanced research and monitoring of a North Carolina estuary; coauthor of a patent for an automated depth profiler.
- First to show that shallow lagoonal estuarine ecosystems are resilient to the adverse effects of hurricanes, recovering within 4-5 years.
- Helped to develop a model for water mass transport to the Neuse Estuary; used the model and a detailed dataset for improved quantification of nutrient loads, including decadal trend analysis.

### **Grants (past decade)**

My research routinely involves analyzing the species composition and abundance of phytoplankton in samples from lakes, reservoirs, rivers, estuaries, and marine coastal environments. For example, my research associate, Ms. Elle Allen, and I recently analyzed 1,000 phytoplankton samples from lakes across the nation as part of a major contract to Dr. Beaver from the U.S. Environmental Protection Agency.

Support for my research and education outreach has been obtained from the National Science Foundation, National Park Service, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, U.S. Department of Defense, the Burroughs Wellcome Fund, the Park Foundation, the Z. Smith Reynolds Foundation, and North Carolina Clean Water Management Trust Fund.

**Publications** (Peer-reviewed, in scientific journals, books and symposia volumes)

- 1) Burkholder JM, Bachmann RW (1979) Potential phytoplankton productivity in three Iowa streams. *Proceedings of the Iowa Academy of Sciences* 86: 22-25.
- 2) Sheath RG, Burkholder JM (1983) Morphometry of *Batrachospermum* populations intermediate between *B. boryanum* and *B. ectocarpum* (Rhodophyta). *Journal of Phycology* 19: 324-331.
- 3) Burkholder JM, Sheath RG (1984) The seasonal distribution, abundance and diversity of desmids (Chlorophyta) in a softwater, north temperate stream. *Journal of Phycology* 20: 159-172.
- 4) Sheath RG, Burkholder JM (1985) Characteristics of softwater streams in Rhode Island. II. Composition and seasonal dynamics of macroalgal communities. *Hydrobiologia* 128: 109-118.
- 5) Burkholder JM, Sheath RG (1985) Characteristics of softwater streams in Rhode Island, U.S.A. I. A comparative analysis of physical and chemical features. *Hydrobiologia* 128: 97-108.
- 6) Bachmann MD, Carlton RG, Burkholder JM, Wetzel RG (1986) Symbiosis between salamander eggs and green algae: Microelectrode measurements inside eggs demonstrate effects of photosynthesis on oxygen concentrations. *Canadian Journal of Zoology* 64: 1586-1588.
- 7) Sheath RG, Burkholder JM, Hambrook JA, Hogeland A, Hoy E, Kane ME, Morison MO, Steinman AD, Van Alstyne KL (1986) Characteristics of softwater streams in Rhode Island. III. Distribution of macrophytic vegetation in a small drainage basin. *Hydrobiologia* 140: 183-191.
- 8) Sheath RG, Burkholder JM, Morison MO, Steinman AD, Van Alstyne KL (1986) Effect of tree canopy removal by gypsy moth larvae on the macroalgae of a Rhode Island headwater stream. *Journal of Phycology* 22: 567-570.
- 9) Moeller RE, Burkholder JM, Wetzel, RG (1988) Significance of sedimentary phosphorus to a rooted submersed macrophyte (*Najas flexilis*) and its algal epiphytes. *Aquatic Botany* 32: 261-281.
- 10) Sheath RG, Burkholder JM (1988) Stream macroalgae, pp. 53-59. In: *Freshwater and Marine Plants of Rhode Island*, by Sheath RG and Harlin MM (eds.). Kendall/Hunt Publishers, Dubuque (IA), 149 pp.
- 11) Burkholder JM, Wetzel RG (1989) Microbial colonization on natural and artificial macrophytes in a phosphorus-limited hardwater lake. *Journal of Phycology* 25: 55-65.
- 12) Burkholder JM, Wetzel RG (1989) Epiphytic microalgae on natural substrata in a hardwater lake: Seasonal dynamics of community structure, biomass, and ATP content. *Archives für Hydrobiologie/Supplement* 83: 1-56.
- 13) Burkholder, J.M. and R.G. Wetzel (1990) Epiphytic alkaline phosphatase on natural and artificial plants in an oligotrophic lake: Re-evaluation of the role of macrophytes as a phosphorus source for epiphytes. *Limnology and Oceanography* 35: 736-747.
- 14) Burkholder JM, Wetzel RG, Klomparens KL (1990) Direct comparison of phosphate uptake by adnate and loosely attached microalgae within an intact biofilm matrix. *Applied and Environmental Microbiology* 56: 2882-2890.
- 15) Cuker BE, Gama P, Burkholder JM (1990) Type of suspended clay influences lake productivity and phytoplankton community response to phosphorus loading. *Limnology and Oceanography* 35: 830-839.
- 16) Burkholder JM, Cuker BE (1991) Response of periphyton communities to clay and phosphate loading in a shallow reservoir. *Journal of Phycology* 27: 373-384.
- 17) Everitt DT, Burkholder JM (1991) Seasonal dynamics of macrophyte communities from a stream flowing over granite flatrock in North Carolina, U.S.A. *Hydrobiologia* 222: 159-172.

- 18) Burkholder JM (1992) Phytoplankton and episodic suspended sediment loading: Phosphate partitioning and mechanisms for survival. *Limnology and Oceanography* 37: 974-988.
- 19) Burkholder JM, Mason KM, Glasgow HB (1992) Water-column nitrate enrichment promotes decline of eelgrass (*Zostera marina* L.): Evidence from seasonal mesocosm experiments. *Marine Ecology Progress Series* 81: 163-178.
- 20) Burkholder JM, Noga EJ, Hobbs CW, Glasgow HB, Smith SA (1992) New "phantom" dinoflagellate is the causative agent of major estuarine fish kills. *Nature* 358: 407-410, *Nature* 360: 768.
- 21) Mallin MA, Burkholder JM, Sullivan MJ (1992) Benthic microalgal contributions to coastal fishery yield. *Transactions of the American Fisheries Society* 121: 691-695.
- 22) Martin TH, Crowder LB, Dumas CF, Burkholder JM (1992) Indirect effects of fish on macrophytes in Bays Mountain Lake: Evidence for a littoral trophic cascade. *Oecologia* 89: 476-481.
- 23) Noga EJ, Smith SA, Burkholder JM, Hobbs CW, Bullis RW (1993) A new ichthyotoxic dinoflagellate: Cause of acute mortality in aquarium fishes. *Veterinary Record* 133: 48-49.
- 24) Burkholder JM, Glasgow HB, Cooke JE (1994) Comparative effects of water-column nitrate enrichment on eelgrass *Zostera marina*, shoalgrass *Halodule wrightii*, and widgeongrass *Ruppia maritima*. *Marine Ecology Progress Series* 105: 121-138.
- 25) Coleman VL, Burkholder JM (1994) Community structure and productivity of epiphytic microalgae on eelgrass (*Zostera marina* L.) under water-column nitrate enrichment. *Journal of Experimental Marine Biology and Ecology* 179: 29-48.
- 26) Burkholder JM, Glasgow HB (1995) Interactions of a toxic estuarine dinoflagellate with microbial predators and prey. *Archiv für Protistenkunde* 145: 177-188.
- 27) Burkholder JM, Glasgow HB, Hobbs CW (1995) Distribution and environmental conditions for fish kills linked to a toxic ambush-predator dinoflagellate. *Marine Ecology Progress Series* 124: 43-61.
- 28) Burkholder JM, Glasgow HB, Steidinger KA (1995) Stage transformations in the complex life cycle of an ichthyotoxic "ambush-predator" dinoflagellate, pp. 567-572. In: *Harmful Marine Algal Blooms*, by Lassus P, Arzul G, Erard E, Gentien P, Marcaillou C (eds.). Lavoisier, Intercept Ltd., Paris.
- 29) Coleman VL, Burkholder JM (1995) Response of microalgal epiphyte communities to nitrate enrichment in an eelgrass (*Zostera marina* L.) meadow. *Journal of Phycology* 31: 36-43.
- 30) Glasgow HB, Burkholder JM, Schmechel DE, Fester PA, Rublee PA (1995) Insidious effects of a toxic dinoflagellate on fish survival and human health. *Journal of Toxicology and Environmental Health* 46: 501-522.
- 31) Lewitus AJ, Jesien RV, Kana TM, Burkholder JM, Glasgow HB, May E (1995) Discovery of the "phantom" dinoflagellate in Chesapeake Bay. *Estuaries* 18: 373-378.
- 32) Mallin MA, Burkholder JM, Larsen LM, Glasgow HB (1995) Response of two zooplankton grazers to an ichthyotoxic estuarine dinoflagellate. *Journal of Plankton Research* 17: 351-363.
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- epidemic disease in estuarine fish. *Marine Pollution Bulletin* 32: 219-224.
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  - 40) Levin ED, Schmechel DE, Burkholder JM, Glasgow HB, Deamer-Melia N, Moser VC, Harry GJ (1997) Persistent learning deficits in rats after exposure to *Pfiesteria piscicida*. *Environmental Health Perspectives* 105: 1320-1325.
  - 41) Mallin MA, Burkholder JM, Shank GC, McIver MR, Glasgow HB, Springer J, Touchette BW (1997) Comparative effects of poultry and swine waste lagoon spills on the quality of receiving stream waters. *Journal of Environmental Quality* 26: 1622-1631.
  - 42) Burkholder JM (1998) Implications of harmful marine microalgae and heterotrophic dinoflagellates in management of sustainable marine fisheries. *Ecological Applications* 8: S37-S62.
  - 43) Burkholder JM, Glasgow HB, Lewitus AJ (1998) Physiological ecology of *Pfiesteria piscicida* with general comments on "ambush-predator" dinoflagellates, pp. 175-191. In: *Physiological Ecology of Harmful Algae*, by Anderson DM, Cembella A, Hallegraeff GM (eds.). NATO ASI Series G: Ecological Sciences, Vol. 41. Springer-Verlag, Berlin, Germany.
  - 44) Burkholder JM, Larsen LM, Glasgow HB, Mason KM, Gama P, Parsons JE (1998) Influence of sediment and phosphorus loading on phytoplankton communities in an urban piedmont reservoir. *Lake and Reservoir Management* 14: 110-121.
  - 45) Glasgow HB, Lewitus AJ, Burkholder JM (1998) Feeding behavior of the ichthyotoxic estuarine dinoflagellate, *Pfiesteria piscicida*, on amino acids, algal prey, and fish vs. mammalian erythrocytes, pp. 394-397. In: *Harmful Microalgae – Proceedings, VIIth International Conference on Harmful Algal Blooms* by Reguera B, Blanco J, Fernandez ML, Wyatt T (eds.). Xunta de Galicia and IOC of UNESCO, Paris, France.
  - 46) Burkholder JM, Glasgow HB (1999) Science ethics and its role in early suppression of the *Pfiesteria* issue. *Human Organization* 58: 443-455.
  - 47) Burkholder JM, Mallin MA, Glasgow HB (1999) Fish kills, bottom-water hypoxia, and the toxic *Pfiesteria* complex in the Neuse River and Estuary. *Marine Ecology Progress Series* 179: 301-310.
  - 48) Burkholder JM, Springer JJ (1999) Signaling in dinoflagellates, pp. 335-359. In: *Microbial Signaling and Communication*, by England RR, Hobbs G, Bainton NJ, Roberts DMcL (eds.). Fifty-Seventh Symposium of the Society for General Microbiology. Cambridge University Press, Oxford, United Kingdom.
  - 49) Fairey ER, Edmunds JS, Deamer-Melia NJ, Glasgow HB, Johnson FM, Moeller PR, Burkholder JM, Ramsdell JS (1999) Reporter gene assay for fish killing activity produced by *Pfiesteria piscicida*. *Environmental Health Perspectives* 107: 711-714.
  - 50) Harvell CD, Kim K, Burkholder JM, Colwell RR, Epstein PR, Grimes J, Hofmann EE, Lipp E, Osterhaus ADME, Overstreet R., Porter JW, Smith GW, Vasta G (1999) Emerging marine diseases:



Climate links and anthropogenic factors. *Science* 285: 1505-1510.

- 51) Levin ED, Simon BB, Schmechel DE, Glasgow HB, Deamer-Melia NJ, Burkholder JM, Moser VC, Jensen K, Harry GJ (1999) *Pfiesteria* toxin and learning performance. *Neurotoxicology and Teratology* 21: 215-221.
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- 156) Flynn, KJ, Mitra A, Stoecker DK, Raven JA, Granéli E, Glibert PM, Hansen PJ, Burkholder JM G. (2012) An ocean of mixotrophs – a new paradigm for marine ecology. *Journal of Plankton Research* 35: 3-11.
- 157) Glibert PM, Burkholder JM, Kana TM (2012) Recent insights about relationships between nutrient availability, forms, and stoichiometry, and the distribution, ecophysiology, and food web effects of pelagic and benthic *Prorocentrum* species. *Harmful Algae* 14: 231-259.
- 158) Hathaway JM, Moore TLC, Burkholder JM, Hunt WF (2012) Temporal analysis of stormwater SCM effluent based on harmful algal bloom (HAB) sensitivity in surface waters: Are annual nutrient EMCs appropriate during HAB-sensitive seasons? *Ecological Engineering* 49: 41-47.
- 159) Burkholder JM, Glibert PM (2013) Eutrophication and oligotrophication, pp. 347-371. *In: Encyclopedia of Biodiversity*, 2<sup>nd</sup> edition, Volume 3, by Levin S (ed.). Academic Press, Waltham, MA.
- 160) Wang W-C, Allen E, Campos AA, Cade RK, Dean L, Dvora M, Immer JG, Mixson S, Srirangan S, Sauer M-L, Schreck S, Sun K, Thapaliya N, Wilson C, Burkholder J, Grunden AM, Lamb HH, Sederoff H, Stikeleather LF, Roberts WL (2013) ASI: *Dunaliella* marine microalgae to drop-in replacement liquid transportation fuel. *Environmental Progress* (November): DOI:10.1002/ep.11855.
- 161) Mitra A, Flynn KJ, Burkholder JM, Berge T, Calbet A, Raven JA, Granéli E, Glibert PM, Hansen PJ, Stoecker DK, Thingstad F, Tillmann U, Våge S, Wilken S, Zubkov M (2013) The role of mixotrophic protists in the biological carbon pump. *Biogeosciences Discussion* 10: 13535-13562.
- 162) Mixson SM, Stikeleather LF, Simmons OD III, Wilson CW, Burkholder JM. (2014) Auto-flocculation, electro-flocculation, and hollow-fiber filtration techniques for harvesting the saltwater microalga *Dunaliella*. *Journal of Applied Phycology* DOI 10.1007/s10811-013-0232-z.
- 163) Glibert PM, Wilkerson FP, Dugdale RC, Raven JA, Dupont C, Leavitt PR, Parker AE, Burkholder JM, Kana TM (2016) Pluses and minuses of ammonium and nitrate uptake and assimilation by phytoplankton and implications for productivity and community composition, with emphasis on nitrogen-enriched conditions. *Limnology and Oceanography* 61: 165-197.
- 164) Gobler CJ, Burkholder JM, Davis TW, Harke MJ, Johengen T, Stow C, Van de Waal DB (2016) The



dual role of nitrogen supply in controlling the growth *and* toxicity of cyanobacterial blooms. *Harmful Algae* (accepted).

165) Mitra A, Flynn KJ, Tillmann U, Raven JA, Caron D, Stoecker DK, Not F, Hansen PJ, Hallegraeff G, Sanders R, Wilken S, McManus G, Johnson M, Pitt P, Våge S., Berge T, Calbet A, Thingstad F, Jeong HJ, Burkholder JM, Glibert PM, Granéli E, Lundgren V (2016) Defining planktonic protist functional groups on mechanisms for energy and nutrient acquisition: Incorporation of diverse mixotrophic strategies. *Protist* (accepted).

166) Burkholder JM, Gobler C, O'Neill J (submitted) Cyanobacteria. In: *Harmful Algal Blooms and Their Management: A Compendium Desk Reference*, by Shumway SE, Burkholder JM, Morton SL (eds.). Funded by a grant from the NOAA Saltonstall-Kennedy Program. Elsevier.

Burkholder JM, Marshall HG (submitted) *Pfiesteria piscicida* and *Pfiesteria shumwayae*. In: *Harmful Algal Blooms and Their Management: A Compendium Desk Reference*, by Shumway SE, Burkholder JM, Morton SL (eds.). Funded by a grant from the NOAA Saltonstall-Kennedy Program. Elsevier.

Burkholder JM, Shumway SE (submitted) Food web and ecosystem impacts from harmful algae. In: *Harmful Algal Blooms and Their Management: A Compendium Desk Reference*, by Shumway SE, Burkholder JM, Morton SL (eds.). Funded by a grant from the NOAA Saltonstall-Kennedy Program. Elsevier.

#### **Technical Reports** (peer-reviewed)

Burkholder JM, Parsons JE (1993) *Sediment and Phosphorus Loading: Predicting Water Quality in Urban Piedmont Reservoirs*. Report No. 274. UNC Water Resources Research Institute, Raleigh, NC, 194 pp.

Burkholder JM, Glasgow HB, Fensin E (1996) *Neuse Estuary Biomonitoring Study – May 1993 – December 1995*. Report of the first three years of a five-year study, to the U.S. Marine Air Station – Cherry Point, Cherry Point, NC. Aquatic Botany Laboratory, NCSU, Raleigh, 86 pp.

Burkholder JM (1998) *The Toxic Pfiesteria Complex: A Scientific Discussion of its History, Ethology, and Impacts on Human Health*. Office, Assistant Secretary of the Army - Installations, Logistics and Environment. Pentagon, Washington, DC.

Burkholder JM, Glasgow HB, Deamer-Melia N (1998) *Neuse Estuary Biomonitoring Study – Physical, Chemical, and Biological Characteristics of Water Samples Collected from the Neuse Estuary in the Vicinity of Cherry Point, North Carolina, May 1993 - April 1998*. Final Report of a five-year study, to the U.S. Marine Air Station, Cherry Point, NC. Aquatic Botany Laboratory, NCSU, Raleigh, 110 pp.

Burkholder JM (1999) *The Role of Toxic Dinoflagellates in Fish Lesions*. Issue paper prepared for the U.S. Army. Office, Assistant Secretary of the Army - Installations, Logistics and Environment. Pentagon, Washington, DC.

Burkholder JM, Glasgow HB (1999) *Neuse Estuary Biomonitoring Study, with Additional Information on Overall Nutrient Loading to the Mesohaline Estuary*. Final Report to the U.S. Marine Air Station – Cherry Point. Department of Botany, NCSU, Raleigh, 134 pp.

Burkholder JM, Glasgow HB, Rublee PA, Shumway SE (2001) *The Toxic Dinoflagellate, Pfiesteria, as a Potential Biosensor of Estuarine Stress*. Final Report to the U.S. EPA, Washington, DC, 108 pp.

Touchette BW, Burkholder JM, Glasgow HB (2001) *Distribution of American Water Willow (Justicia americana L.) in the Narrows Reservoir*. Final Report to Alcoa Power Generating Inc., Badin, NC, 51 pp.

van der Schalie WH, Shedd T, Widder M, Kane AS, Reimschuessel R, Sarabun J, Burkholder J, Glasgow H (2001) *Real-Time Monitoring for Toxicity Caused by Harmful Algal Blooms and Other Water Quality*

- Perturbations*. Report EPA/600/R-01/103, U.S. EPA, Washington, DC.
- Burkholder J, Glasgow H, Deamer N, Melia G, Litzenberger T (2003) *Response of Pfiesteria piscicida, Microbial Predators and Prey, and Fish to Common Dithiocarbamate Fungicides and Heavy Metals*. Final Report to the U.S. EPA, Research Triangle Park, NC, 26 pp. + appendix.
- Burkholder JM (2010) *Assessment of Water Resources and Watershed Conditions in the Kennesaw Mountain National Battlefield Park, Georgia*. Draft Report to the Southeast Coast Inventory and Monitoring Network of the National Park Service, Southeast Regional Office, Atlanta, GA, 71 pp.
- Burkholder JM, Allen EH, Kinder CA (2010) *Assessment of Water Resources and Watershed Conditions in Ocmulgee National Monument, Georgia*. Natural Resource Report NPS/SECN/NRR—2010/276. National Park Service, Fort Collins, CO, 81 pp.
- Burkholder JM, Allen EH, Kinder CA, Morris E (2010) *Assessment of Water Resources and Watershed Conditions in the Chattahoochee River National Recreation Area, Georgia*. Draft Natural Resource Report NPS/SECN.NRR-2010/274. National Park Service, Fort Collins, CO, 202 pp.
- Burkholder JM, Rothenberger MB (2010) *Assessment of Water Resources and Watershed Conditions in Horseshoe Bend National Military Park, Alabama*. Natural Resource Report NPS/SECN.NRR-2010/268. National Park Service, Fort Collins, CO, 51 pp.
- United States Department of Environmental Protection (U.S. EPA) (2011) *Efficacy of Ballast Water Treatment Systems: A Report by the EPA Science Advisory Board (SAB)*. U.S. EPA SAB Ecological Processes and Effects Committee Augmented for the Ballast Water Advisory. Report #EPA-SAB-11-009. U.S. EPA, Washington, DC, ~150 pp. Burkholder was an Augmented Panel Member and a coauthor of this report.
- Burkholder JM, Allen EH, Flood S, Kinder CA (2015) *Inventory and Assessment of Natural Resources in Horseshoe Bend National Military Park, Alabama*. Natural Resource Report NPS/SECN/NRTR—2015/981. National Park Service, Fort Collins, CO, 270 pp.
- Burkholder JM, Allen EH, Flood S, Kinder CA (2016, accepted) *Inventory and Assessment of Natural Resources in Ocmulgee National Monument, Georgia*. Natural Resource Report NPS/SECN/NRTR—2016/xxx. National Park Service, Fort Collins, CO, 179 pp.
- Burkholder JM, Allen EH, Flood S, Kinder CA (2016, accepted) *Inventory and Assessment of Natural Resources in Kennesaw Mountain National Battlefield, Georgia*. Natural Resource Report NPS/SECN/NRTR—2016/xxx. National Park Service, Fort Collins, CO, 220 pp.
- Burkholder JM, Allen EH, Flood S, Kinder CA (2016, accepted) *Inventory and Assessment of Natural Resources in the Chattahoochee River National Recreation Area, Georgia*. Natural Resource Report NPS/SECN/NRTR—2016/xxx. National Park Service, Fort Collins, CO, 339 pp.
- Burkholder JM, Allen EH, Flood S, Kinder CA (2016, accepted) *Inventory and Assessment of Natural Resources in Moores Creek National Battlefield, North Carolina*. Natural Resource Report NPS/SECN/NRTR—2016/xxx. National Park Service, Fort Collins, CO, 202 pp.
- Burkholder JM, Allen EH, Flood S, Kinder CA (2016, accepted) *Inventory and Assessment of Natural Resources in Congaree National Park, South Carolina*. Natural Resource Report NPS/SECN/NRTR—2016/xxx. National Park Service, Fort Collins, CO, 324 pp.
- Burkholder JM, Allen EH, Flood S, Kinder CA (2016, accepted) *Inventory and Assessment of Natural Resources in Cape Hatteras National Seashore, North Carolina*. Natural Resource Report NPS/SECN/NRTR—2016/xxx. National Park Service, Fort Collins, CO, 341 pp.
- Burkholder JM, Allen EH, Flood S, Kinder CA (2016, accepted) *Inventory and Assessment of Natural*

*Resources in Cape Lookout National Seashore, North Carolina*. Natural Resource Report NPS/SECN/NRTR—2016/xxx. National Park Service, Fort Collins, CO, 248 pp.

Burkholder JM, Allen EH, Flood S, Kinder CA (2016, accepted) *Inventory and Assessment of Natural Resources in Cumberland Island National Seashore, Georgia*. Natural Resource Report NPS/SECN/NRTR—2016/xxx. National Park Service, Fort Collins, CO, 292 pp.

Burkholder JM, Allen EH, Flood S, Kinder CA (2016, submitted) *Inventory and Assessment of Natural Resources in Timucuan Ecological and Historic Preserve, Florida*. Natural Resource Report NPS/SECN/NRTR—2016/xxx. National Park Service, Fort Collins, CO, 362 pp.

### **Non-Referred and Popular Press Articles**

Burkholder JM (2006) A major potable water supply reservoir poised for increased cyanobacteria blooms. *LakeLine* (summer), pp. 49-51.

Burkholder JM (2003) Science and the press. On-line modules (editor, N. Kriesberg), NCSU, Raleigh.

Schmechel DE, Burkholder JM, Attix DK, Glasgow HB (2002) Toxic *Pfiesteria*. Microbiology No. MB 02-5 (MB-036). *Check Sample, American Society for Clinical Pathology* 45:65-88.

Burkholder JM (2000) Brushstrokes from Floyd, pp. 72-79. In: *Eye of the Storm – Essays in the Aftermath*, by E.W. Rickert (ed.). Coastal Carolina Press, Wilmington.

President's Committee of Advisors on Science and Technology (PCAST) (1998) *Teaming with Life: Investing in Science to Understand and Use America's Living Capital*. Section I: Make Use of Current Knowledge in Managing Biodiversity and Ecosystems of the U.S., p.27. PCAST Panel on Biodiversity and Ecosystems, Washington, DC.

Burkholder JM (1997) *Pfiesteria* and Nutrient Pollution. Requested by Maryland's Governor Glendening for a summit meeting of five governors of states in the Chesapeake Bay watershed, Annapolis, pp. 1-5.

Burkholder JM (1995) Fish kills' message: Get serious about reducing nutrient over-enrichment to our estuaries, pp.1-3. In: *WaterWise*, by Doll B (Ed.). Vol. 1, 2<sup>nd</sup> Quarter. NC Sea Grant News Letter, Raleigh.

Coastal Futures Committee (1994) *Charting a Course for our Coast - A Report to the Governor of North Carolina*. L.R. Preyer, Chair. NC Department of Environment, Health and Natural Resources, Raleigh, 106 pp. [As the only scientist on the 15-member committee, I contributed substantially to all sections related to water quality, habitat, and fisheries in the document, and to the executive summary of prioritized recommendations.]

Burkholder JM (1993) Vital grasses need clean water to grow. In: *Currents*, News Letter of the Pamlico-Tar River Foundation, Vol. 13, Fall, p.7, Washington (NC).

Burkholder JM (1993) A newly discovered toxic alga and its relationship to fish kills, pp.48-58. In: *Proceedings from the Second North Carolina Marine Recreational Fishing Forum*. NC Sea Grant Report UNC-SG-93-06. UNC Sea Grant, NCSU, Raleigh, 61 pp.

Burkholder JM (1993) Golf course runoff: View from below the water surface, pp. 18-23. In: *Is Golfing Green? The Impact of Golf Courses on the Coastal Environment*. Symposium Proceedings (sponsored by the NC Coastal Federation and the NCSU Cooperative Extension Service through the NC Sea Grant College Program), Wilmington.

## **Patent**

U.S. Patent #7,040,157. “Variable depth automated dynamic water profiler”, Reed, Glasgow, Burkholder, Toms, May 2006 (NCSU; patent sold to YSI, Inc.).

## **Professional Activities** (examples)

### ***Editorial***

Guest Co-Editor, special issue, *Harmful Algae* (Intraspecific Variation, 2009)

Guest Co-Editor, special issue, *Harmful Algae* (Harmful Algae and Eutrophication), 2007

Guest Co-Editor, special issue, *Harmful Algae* (Ecology of *Pfiesteria*), 2006

Editorial Board, *Journal of Experimental Marine Biology and Ecology*, 2005 - present

Editorial Board, *Harmful Algae*, 2002 - present

Editorial Board, *Journal of Eukaryotic Microbiology*, 1996-1999

Editorial Board, *Journal of Phycology*, 1995-1997

### ***Other Society Service***

Member, Organizing Committee, International Symposium on Harmful Algae, 2009-2010

Member, Organizing Committee, National Symposium on Harmful Algae, 2000, 2002, 2003

Member, Ethics Committee, American Society of Limnology and Oceanography, 1996-1997

Member, Harmful Algae Technical Advisory Committee, Maryland Department of Natural Resources, 1998-2001

Session Chair, Ecology of Aquatic Protozoa session, XIth Meeting, International Congress of Protozoology, 2001

Session Chair, New Harmful Algae, 10<sup>th</sup> International Conference on Harmful Algal Blooms, 2000

Session Chair, *Pfiesteria* in the Southeast, 1<sup>st</sup> National Symposium on Harmful Algae, 2000

Session Chair, Harmful Algae, 15<sup>th</sup> Biennial International Conference of the Estuarine Research Federation, 1999

Session Co-Chair, Harmful Algal Blooms, Annual Summer Meeting, American Society of Limnology and Oceanography, 1998

Session Co-Chair, Harmful Algal Blooms, Joint Meeting - American Society of Limnology and Oceanography and American Geophysical Union, 1997

Chair, Hutchinson Award Committee, American Society of Limnology and Oceanography, 1996

Board of Directors, American Society of Limnology and Oceanography, 1994-1997

Session Chair, Ecology of Freshwater Algae, Joint Meeting - International Phycological Congress and Phycological Society of America, 1991

Session Chair, Phytoplankton, Annual Meeting, American Society of Limnology and Oceanography, 1988

### ***External Panels and Reviews***

Member, panel review of the annual South Florida Environmental Report for the South Florida Water Management District, 2006-2011

Examiner (“Opponent”) of doctoral candidate Johannes Hagström, Kalmar University, 2006

Member, review team for the Department of Botany, Miami University of Ohio, 2005

Member, review team for the Marine Sciences Programs, Institut für Meereskunde, Salzgau, Germany, 1998

National Science Foundation, Biological Oceanography Panel, 1995

UNC Water Resources Research Institute Panel, 1991-1993

Member, review team, Lake Okechobee Ecosystem Project, South Florida Water Management District, 1991

### ***Workshops*** (Invited Participant)

The Importance of Algal Mixotrophy in Trophic Models of the Oceans – participant and invited speaker of

an international workshop sponsored by the Leverhume Foundation, University of Maryland - Horn Point, Cambridge, MD, 2013

Taxonomy and Ecology of Algae in the Southeast – co-organizer of a workshop for members of the North Carolina Lake Management Society (NALMS – Southeast Chapter), sponsored by NALMS, 2009, 2010, 2011, 2012

Falls Lake Symposium: Christian Creation Stewardship – keynote speaker of a workshop attended by scientists and theologians, to encourage church memberships to become involved in environmental stewardship of the Falls Lake potable water supply, sponsored by the concerned citizens group, Wake Up Wake County, and organized by Drs. Bob George (editor, Theocology Journal online) and Bruce Little (Center for Faith and Culture, Southeastern Theological Seminary), 2012

Algae Affecting Potable Water Supplies – AWWA, Savannah, GA, 2010

Identifying Harmful Cyanobacteria in North Carolina Potable Water Supplies – Organizer; two workshops for potable water treatment plant operators, sponsored by the NC Department of Health and Human Services, 2006

Occurrence of Toxigenic Cyanobacteria in the USA, International Symposium on Harmful Cyanobacterial Blooms, US Environmental Protection Agency (EPA), 2005

National Plan for Harmful Algal Research, Ecological Society of America and the National Oceanic and Atmospheric Administration (NOAA), 2004

Social and Environmental Impacts of Concentrated Animal Feed Operations, The University of Iowa and the National Institute of Environmental Health Sciences (NIEHS), 2004

Conflicted Science / Integrity in Science Conference and Workshop, Center for Science in the Public Interest, Washington, DC, 2003

Estuarine Fish Disease, Delaware Department of Natural Resources & Environmental Control, 2000

Harmful Algae Technical Advisory Committee Workshop, Maryland Department of Natural Resources (MD DNR) and Maryland Department of Environment (MD DE), 2000, 2001, 2002

Re-evaluation of Microbial Water Quality: Powerful New Tools for Detection and Risk Assessment, American Academy of Microbiology, 2000

Conservation Medicine Workshop, Center for Conservation Medicine of Tufts University, 1999

Harmful Algal Blooms: Research and Monitoring Programs, US EPA - Region IV, 1998

*Pfiesteria* Workshops - Sampling and Identification (organizer), NCSU, 1998

*Pfiesteria* Sampling and Identification Protocols, Centers for Disease Control & Prevention, 1998

European Harmful Algal Blooms (EUROHAB) Science Initiative, Marine Science and Technology Programme of the European Commission, 1998

*Pfiesteria* and Water Quality Monitoring Standards Workshop, NOAA, 1998

*Pfiesteria* and Human Health Workshop, Maryland Department of Health and Mental Hygiene and the Maryland Medical Team, University of Maryland and Johns Hopkins, 1998

State/Federal *Pfiesteria* Working Group - Monitoring Protocols, U.S EPA and NOAA, 1998

Maryland Technical Advisory Committee Workshop on *Pfiesteria*, Fish Kills and Water Quality Monitoring, MD DNR, Baltimore, MD, 1998

*Pfiesteria* Workshop, 14<sup>th</sup> Biennial International Conference of the Estuarine Research Federation, Providence, RI, 1997

The Cambridge *Pfiesteria*/Nutrients Workshop, convened by Governor Glendening of Maryland, 1997. The final report, *The Cambridge Consensus*, was used by the governor and the Maryland legislature to change policy about non-point water pollution control in tributaries to Chesapeake Bay and led to passage of the Maryland Water Quality Act of 1998.

Impacts of Toxic *Pfiesteria*/*Pfiesteria*-like Dinoflagellates on Fisheries and Human Health, US EPA (Philadelphia, PA; Washington, DC; Pensacola, FL), 1997; Delaware Department of Environment and Water Resources, 1997

Harmful Algal Blooms and Human Health, NIEHS, 1997

Pocomoke River Fish Disease, MD DNR, 1997  
 Climate Variability and Human Health, American Society of Microbiology, 1997  
 Developing an Environmental Education Video on Water Resource Issues in North Carolina,  
 Z. Smith Reynolds Foundation, 1997  
 Control of Blue-Green Algae in Rainbow Springs, Florida, Department of Fisheries and Aquaculture,  
 University of Florida, 1996  
 Sustainable Marine Fisheries, National Academy of Sciences Ocean Studies Board, 1996  
 Disease Events and Meteorology along the US Atlantic Coast, Harvard Medical School, 1995  
 National Nutrient Assessment Workshop – Estuaries, US EPA, Washington, DC, 1995  
 Harmful Algal Blooms - Research Initiative Development, NSF / NOAA, 1994  
 Seagrasses and Eutrophication Impacts, US EPA / Sarasota Bay National Estuary Program, 1993  
 Techniques in Sampling and Identification of *Pfiesteria* – NOAA, 1992; Florida Department of  
 Environmental Protection - Florida Marine Research Institute, 1992; MD DNR, 1993; MD DE, 1993;  
 Delaware Division of Water Quality, 1993  
 Target Issues: Development of RFP guidelines for a New NOAA Coastal Ocean Program Initiative on  
 Harmful Algal Blooms, NOAA, 1992  
 Phytoplankton of the Southeastern United States, North Carolina Department of Environment, Health and  
 Natural Resources (NC DEHNR) and Duke Power Company, 1992  
 Target Issues for Funding Support of Research on Toxic Phytoplankton, NOAA, 1992  
 Improved Data Base and Optimal Approaches for Modeling Water Quality in the Albemarle-Pamlico  
 Estuarine System, US EPA and NC DEHNR, 1992  
 Water Quality Regulations for Protection of Seagrass Habitat on the Gulf Coast, US EPA, 1992  
 Improved Standards for Protecting Water Quality in the Albemarle-Pamlico Estuarine System, US EPA, 1991  
 Teaching Aquatic Botany to High School Students (organizer), NCSU, 1987, 1988  
 Light Microscope-Autoradiography of Microalgae (organizer), Bowling Green State University, Bowling  
 Green, OH, 1987

## **Research Presentations**

*Water Quality* (Eutrophication, Seagrasses, etc.)

### 2015

Decadal Analysis of Water Quality in Falls Lake, the Triangle's Major Potable Water Source (Burkholder et al., presentation and published abstract). Annual conference of the UNC Water Resources Research Institute, Raleigh, NC.

### 2014

Long-Term Data Show Continued Water Quality Degradation in the Neuse Estuary, and Inadequate Protection by the Total Nitrogen TMDL (Burkholder et al., presentation and published abstract). Annual conference of the UNC Water Resources Research Institute, Raleigh, NC.

Why Bother? - Who Needs Models for Mixotrophs in Coastal Ecosystems? (invited presentation, Burkholder) Leverhulme Trust Phytoplankton Mixotrophy Workshop, Swansea, United Kingdom.  
 Unprecedented Toxin-Producing Cyanobacterial Blooms in the Cape Fear River (Mallin et al., presentation and published abstract), Summer Meeting of the Sciences of Limnology and Oceanography, San Diego, CA.

### 2013

Outside Peer Review of the Marine Programs of the UNC System for the UNC Board of Governors, Morehead City, NC - The NCSU CAAE was later given an excellent evaluation by the Panel in its final report.

Coastal and Estuarine Research Federation, San Diego, CA - Onset of unprecedented toxin-producing

cyanobacteria blooms in the Cape Fear River system, North Carolina - Mallin MA., Burkholder JM, McIver MR, Metheny JD, Strangman WK, Zimba PV, Wright JL (presentation, with published abstract).

Coastal and Estuarine Research Federation, San Diego, CA - Comparative ecotoxicology of an agricultural herbicide on benign and toxigenic estuarine phytoplankton - Flood S, Burkholder J, Cope G. (poster, with published abstract).

## 2012

UNC Water Resources Research Institute, Raleigh, NC – The NCSU Center for Applied Aquatic Ecology Falls Lake Monitoring and Research Program - Burkholder J, Reed R, Kinder C, Allen E, James J, Mackenzie L (poster, with published abstract)

Falls Lake Creation Care Symposium, Wake Forest, NC - Status of Water Quality in Falls Lake - J. Burkholder. The goal of this national symposium was for scientists to inform theologians about citizens' potential roles, including church congregations, in assisting with natural resource stewardship issues (keynote presentation, with published abstract)

## 2011

UNC Water Resources Research Institute, Raleigh, NC (excessive ammonium concentrations throughout the Falls Lake water column, and implications for the Falls Lake Rules - with published abstract)

American Water Works Association National Webinar, online technology used to monitor algae and associated environmental conditions (invited, with published abstract)

LOICZ Open Science Conference 2011 – Coastal Systems, Global Change and Sustainability, Yantai, China (Shumway SE, Burkholder JM: mitigating coastal eutrophication – are filter-feeding shellfish the answer?) (plenary, with published abstract)

## 2010

UNC Water Resources Research Institute, Raleigh, NC (status of water quality in the most important potable water supply in North Carolina - with published abstract)

## 2009

National Shellfisheries Association, Savannah, GA (bivalve shellfish aquaculture and eutrophication)

North Carolina Academy of Science, Warren Wilson College, Swannanoa, NC (documenting microbial changes in reservoirs using metagenomics – coauthor)

Department of Civil and Environmental Engineering, Northwestern University, Chicago, IL (decadal analysis of land use, water quality, and phytoplankton assemblages in a coastal watershed)

20<sup>th</sup> Biennial Conference of the Coastal and Estuarine Research Federation (increasing ammonium in eutrophic estuaries, and its potential importance in governing phytoplankton assemblages)

## 2008

Department of Occupational and Environmental Health, U IA (water quality and algal blooms in watersheds influenced by industrialized agriculture)

NOAA National Symposium on Shellfish and the Environment, Warwick, RI (chronic effects of eutrophication on shellfish)

American Society of Limnology and Oceanography, St. Johns, Newfoundland, Canada (microdynamics of physical/chemical structure in a lagoonal estuary - lead, R. Reed; with published abstract)

North Carolina Water Quality Monitoring Forum, Charlotte (recent advances in technology for tracking algal blooms and related environmental conditions; with published abstract)

## 2007

Horn Point Environmental Laboratory, U MD (chronic eutrophication of the Neuse Estuary)

UNC Water Resources Research Institute, Raleigh (CAAE's Falls Lake Monitoring and Research Program; with published abstract)

UNC Water Resources Research Institute, Raleigh (groundwater and benthic nitrogen flux in the Neuse

Estuary - lead, K. Null; poster with published abstract)  
UNC Water Resources Research Institute, Raleigh (long-term impacts of changing land use practices on water quality and phytoplankton assemblages in the Neuse River ecosystem - lead, M. Rothenberger; poster with published abstract)  
Annual Conference of the North Carolina Academy of Science, Greenville (inorganic nitrogen flux across the sediment-water interface in the Neuse Estuary - lead, K. Null; poster with published abstract).  
Conference, Water Initiatives: What's on the Horizon for Lake Users and Managers, Greensboro.  
19<sup>th</sup> Biennial Conference of the Estuarine Research Federation, Norfolk, VA (temporal and spatial variability in high-resolution, cross-estuarine physical/chemical structure in the Neuse Estuary – lead, R. Reed; poster with published abstract).  
19<sup>th</sup> Biennial Conference of the Estuarine Research Federation, Norfolk, VA (multivariate analysis of phytoplankton and environmental factors in a eutrophic estuary - lead, M. Rothenberger; poster with published abstract).

#### 2006

Department of Biology, Cornell University (water quality trends in the Neuse Estuary)  
Department of Marine Sciences, U CONN (water quality trends in the Neuse Estuary)

#### 2005

Department of Biology, UNC Greensboro (water quality trends in the Neuse Estuary)  
Wilkes Community College, Wilkesboro, NC (honors seminar series - water quality issues)

#### 2003

Center for Science in the Public Interest: Conflicted Science Conference, Washington, DC (water quality and confined animal feed operations [CAFOs] - with published abstract)  
Yale University - Conference, The Chicken (environmental impacts of CAFOs - with published abstract)

#### 2002

Medical School, Harvard University (marine diseases, anthropogenic influences)  
Wilkes Community College, Wilkesboro (honors seminar series - water quality issues)

#### 2001

Washington College (Chesterton, MD; environmental impacts of CAFOs)  
Veterinary, Wildlife and Ecological Toxicology Department, Veterinary Biosciences College of Veterinary Medicine, U IL (national water quality issues)  
School of Design, NCSU (environmental effects of CAFOs)  
Wilkes Community College (honors seminar series - water quality issues)  
American Society of Agronomy and the Soil Science Society of America (Northeast Branch) – annual meeting, URI (environmental effects of CAFOs; with published abstract)

#### 2000

American Fisheries Society - annual meeting, St. Louis, MO (environmental effects of CAFOs – with published abstract).  
American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America - joint meeting, Minneapolis, MN (nutrient management on CAFOs, and effects on surface water resources - with published abstract)  
Association of Southeastern Biologists, Chattanooga, TN: Plenary Speaker (national water quality issues - with published abstract)  
Rock Valley College - Natural Resources and Community Action Series, Rockford, IL: Plenary Speaker (national water quality issues)  
U MASS, Amherst - Environmental Policy Seminar Series (invited; national water quality issues)  
Yale University, School of Forestry (national and state water quality issues)



Department of Zoology, U WA - Seattle (national water quality issues)  
American Fisheries Society (NC chapter), New Hill, NC (impacts of Hurricane Floyd on water quality in the Neuse River and Estuary, and Pamlico Sound - with published abstract)

1999

US Department of Agriculture - National Resources Conservation Service, Washington, DC (state water quality issues)  
Simon Fraser University - Oceans Limited Conference, Vancouver, British Columbia, Canada (chronic effects of eutrophication - with published abstract)  
Department of Biology, University of Louisville, Louisville, KY (chronic effects of eutrophication)

1998

Society of Environmental Toxicology and Chemistry - annual meeting, Charlotte, NC: Keynote Speaker (effects of chronic eutrophication - with published abstract)

1997

Conference, Nutrients in the Neuse River: Working Toward Solutions (sponsor, UNC Water Resources Research Institute [WRRI]), NCSU (effects of chronic eutrophication - with published abstract)

1996

National Association of Biology Teachers - annual meeting, Charlotte, NC (effects of chronic eutrophication - with published abstract)  
Texas A&M University, Corpus Christi (effects of pulsed nutrient enrichment on seagrass physiology)  
Department of Zoology, Oregon State University (OSU), Corvallis (seagrasses and eutrophication)

1995

Statewide Nutrient Summit (sponsors, NC Sea Grant, NC DEHNR), NCSU (effects of chronic eutrophication - with published abstract)  
Water Quality Research and Extension Overview, College of Agriculture and Life Sciences (CALs), NCSU (surface water quality research in CALs - with published abstract)

1994

NC Academy of Sciences - annual meeting, Manteo - Keynote Speaker (state water quality issues - with published abstract)

1993

UNC WRRI Seminar Series, Keynote Accomplishments in Research on Water Resources in NC, Raleigh (seagrasses and water-column nitrate enrichment - with published abstract)  
Horn Point Environmental Laboratory, U MD (seagrasses and water-column nitrate enrichment)

1992

UNC WRRI Seminar Series, Keynote Accomplishments in Research on Water Resources in NC (sediment and phosphorus loading: predicting reservoir water quality – with published abstract)  
American Society of Limnology and Oceanography - annual meeting, Edmonton, Alberta, Canada (seagrasses and eutrophication - with published abstract)

1990

Department of Zoology, U WI - Madison (algal phototrophy vs. heterotrophy in turbid reservoirs)

1987

Department of Biology, Bowling Green State University, Bowling Green, OH (biological interactions that structure stream plant communities)

1986 (nutrient interactions - macrophytes, epiphytes)

Department of Botany, NCSU

Department of Biology, Fordham University, Bronx, NY

Savannah River Ecology Laboratory, Aiken, SC

University of Michigan Biological Station, University of Michigan, Pellston, MI

1985

Department of Biology, West Virginia University, Morgantown, WV - importance of benthic microalgae in stream ecosystems

Massachusetts Audubon Society, Lincoln, MA - effects of acid deposition on aquatic ecosystems

### ***Harmful Algal Research***

2013

Leverhume Foundation International Workshop, U MD - Horn Point, Cambridge, MD (algal mixotrophy and water-column nutrients)

2010

North American Lake Management Society (NALMS), Winston-Salem, NC (climate change and harmful algal blooms in the Southeast - with published abstract)

Webinar Lecture Series, Northwestern University, given at the University of British Columbia, Vancouver, BC, Canada (overview on harmful algae)

2008

Burdick Lecture, Department of Biology, Alfred University, Alfred, NY (*Pfiesteria*, other harmful dinoflagellates - toxicity, impacts)

Annual Toxicology and Risk Assessment Conference, Cincinnati, OH (the toxins of inland algae - with published abstract)

2007

Joint meeting of the Phycological Society of America and the International Society of Protozoologists (cyanobacteria in eutrophic turbid impoundments of the North Carolina Piedmont - lead, J. Burkholder; poster with published abstract)

Joint meeting of the Phycological Society of America and the International Society of Protozoologists (axenic cultivation of a heterotrophic dinoflagellate - lead, H. Skelton; with published abstract)

4<sup>th</sup> National Symposium on Harmful Algae, Woods Hole, MA (axenic cultivation of *Pfiesteria shumwayae* on a semi-defined medium; poster with published abstract)

2006

Kalmar University, Kalmar, Sweden (*Pfiesteria*, other harmful dinoflagellates - toxicity, impacts)

American Society of Limnology and Oceanography - annual summer meeting: Plenary Speaker, Victoria, British Columbia, Canada (stimulation of harmful algae by eutrophication – with published abstract)

2005

North American Lake Management Society (NALMS) - National Meeting, U WI - Madison – Keynote Speaker (cyanobacteria in potable water supplies - with published abstract)

GEOHAB (Global Ecology and Oceanography of Harmful Algal Blooms) Symposium, Nutritional Ecology of Harmful Algae, Baltimore, MD (importance of intraspecific variation – with published abstract)

Medical School, Harvard University (harmful algae and seafood safety)

NALMS Southeast Chapter Meeting, Asheville, NC (cyanobacteria in potable water supplies - with published abstract)

American Water Works Association - Source Water Protection Symposium, West Palm Beach, FL (cyanobacteria in potable water supplies - with published abstract)

## 2004

XI<sup>th</sup> International Conference on Harmful Algae, Cape Town, South Africa: Plenary Speaker (intraspecific variation in toxicity, behavior and nutrition - with published abstract)

St. Johns Water Management District, Orlando, FL (effects of harmful algae on fish and mammalian health)

International EnviroVet Program, Harbor Branch Oceanographic Institute, Fort Pierce, FL (marine diseases)

Department of Oceanography, U WA - Seattle (science, policy)

Shannon Point Marine Laboratory, Western Washington University (science, policy)

NSF Undergraduate Education Honors Program, NCSU (science, policy)

## 2003

Elon University - Voices of Discovery Seminar Series: Keynote Speaker (*Pfiesteria*)

International EnviroVet Program, Harbor Branch Oceanographic Institute (toxic dinoflagellates)

Florida Institute of Technology (toxic dinoflagellates)

Conference on Emerging Waterborne Pathogens, NC Department of Health and Human Services (DHHS), Wilmington, NC: Two presentations - toxic dinoflagellates; toxic cyanobacteria)

## 2002

Hopkins Marine Laboratory, Stanford University, Monterey, CA (*Pfiesteria*, other toxic dinoflagellates - science, policy, science ethics)

National Ocean Service, NOAA, Charleston, SC (progress in *Pfiesteria* research)

Symposium, Climate Change and Fisheries in the Gulf of Maine (sponsor, NOAA), College of the Atlantic, Bar Harbor, ME (harmful algae and climate change)

Department of Biology, UNH, Durham (toxic dinoflagellates).

Department of Biology, Williams College, Williamston, MA (toxic dinoflagellates)

Department of Biology, Miami University of Ohio, Athens (toxic dinoflagellates)

## 2001

XI<sup>th</sup> International Congress of Protozoology, Salzburg, Austria (dinoflagellates - complex life histories and feeding behaviors – with published abstract)

George Clark Lecture Series, Wetlands Institute, Cape May, NJ (*Pfiesteria*, other dinoflagellates)

Society for Risk Analysis, Research Triangle Park (biomarkers for species and toxins)

Environmental Lecture Series, Ashland University, Ashland, OH (harmful algae and eutrophication)

Marine Conservation Biology Series, Wheaton College, Springfield, MA (chronic effects of harmful algae on fish and mammalian health)

## 2000

IX<sup>th</sup> International Conference on Harmful Algal Blooms, Hobart, Tasmania, Australia: Plenary Speaker (toxic *Pfiesteria* - with published abstract)

Elliott-Nowell-White Symposium, Delta State University, Delta State, MS: Keynote Speaker (chronic and sublethal impacts of harmful algae on mammalian health)

Society of Toxicology of Canada - annual meeting, Montreal, Quebec, Canada (toxic dinoflagellates - with published abstract)

Department of Biology, State University of NY - Syracuse (toxic dinoflagellates)

Brookhaven National Laboratory, Brookhaven, NY (toxic dinoflagellates)

State University of New York - Stony Brook (toxic dinoflagellates)

XIII<sup>th</sup> World Congress of the International Society of Toxinology, Paris, France (toxic *Pfiesteria*)

Centers for Disease Control & Prevention, Atlanta - conference, *Pfiesteria*: From Biology to Public Health (ecology and conservative analysis of role in fish kills - with published abstract)

National Association of Biology Teachers - Biotechnology Conference. VPI, Blacksburg (harmful algal research)

University of Mississippi, Oxford - Conference, Sustainability of Wetlands and Water Resources (toxic

dinoflagellates)

Department of Biology, University of Memphis (toxic dinoflagellates)

Society of Microbiology - Northeast Chapter, Sturbridge, MA (toxic dinoflagellates)

Society of Toxicology - annual meeting (sponsor, US EPA), Philadelphia (toxic dinoflagellates - with published abstract)

Southeastern Estuarine Research Society - annual meeting in conjunction with the 29<sup>th</sup> Benthic Ecology Meeting and the annual meeting of the Atlantic Estuarine Research Society, Wilmington, NC (toxic dinoflagellates - with published abstract)

#### 1999

National Academy of Sciences - Workshop on Critical Research Needs, Washington, DC (research needs to advance understanding about harmful algae)

Lake Biwa Research Institute, Forum on Water Quality, Kyoto, Japan: Keynote Speaker (*Pfiesteria*, other toxic dinoflagellates)

Woods Hole Oceanographic Institute, Falmouth, MA (toxic dinoflagellates)

Veterinary School, Tufts University, Grifton, MA (toxic dinoflagellates)

Department of Biology, Yale University (improved mitigation of harmful algal blooms)

Georgetown Conference on Policy and *Pfiesteria*, Georgetown University, Washington, DC: Keynote Speaker (science, policy of *Pfiesteria* - with published abstract)

American Association for the Advancement of Science (AAAS) - annual meeting, Anaheim, CA, session, "Human Health Risks in the Ocean" (chronic and sublethal impacts - with published abstract)

AAAS - annual meeting, Anaheim, CA, session "Harmful Algal Blooms" (toxic *Pfiesteria* - with published abstract)

Department of Geology, University of Oslo (Oslo, Norway) (toxic *Pfiesteria*)

Society of Protozoologists - annual meeting, Raleigh: Keynote Speaker (toxic *Pfiesteria* - with published abstract)

Department of Ecology Evolution and Behavior, U MN - Minneapolis (toxic dinoflagellates - with published abstract)

Phi Beta Kappa Seminar Series, Elon University (toxic *Pfiesteria*)

Honors Seminar Series, Southampton College, Southampton, NY (toxic dinoflagellates)

Department of Biology, Barton College, Wilson (toxic dinoflagellates)

Department of Biology, Davidson College, Davidson (toxic dinoflagellates)

Wilkes Community College, Wilkesboro (toxic dinoflagellates)

Department of Biology, NC A&T University, Greensboro (toxic dinoflagellates)

Department of Pathology, UNC Chapel Hill (toxic dinoflagellates)

Department of Biology, UNC Greensboro (toxic dinoflagellates)

Department of Biology, University of Louisville (toxic dinoflagellates)

Sigma Xi - NC Chapter meeting, Appalachian State University, Boone, NC (toxic *Pfiesteria*)

#### 1998

AAAS - annual meeting, Philadelphia, session, "Management of Harmful Marine Microbes: When Science and Politics Don't Mix" (harmful algae - with published abstract)

Medical School, Harvard University (harmful algae)

Shallow Water Conference (sponsor, US EPA), Atlantic City, NJ: Keynote Speaker (effects of toxic *Pfiesteria* on fish and mammals - with published abstract)

Gordon Conference - annual meeting, Ventura, CA (acute/chronic effects of toxic dinoflagellates - with published abstract)

Department of Biology, Rutgers University (chronic effects of toxic dinoflagellates)

Department of Biology, URI (toxic dinoflagellates)

Department of Pharmacology, U GA - Athens (toxic dinoflagellates)

American Biological Safety Association - 41<sup>st</sup> Annual Biological Safety Conference, Lake Buena Vista, FL: Eagleston Lecture (*Pfiesteria*, other toxic dinoflagellates - with published abstract)  
 Wildlife Disease Association - 47<sup>th</sup> Annual Conference, U WI - Madison (toxic *Pfiesteria* - with published abstract)  
 Department of Biology, Purdue University (toxic dinoflagellates)  
 American Institute of Biological Sciences - 49<sup>th</sup> annual meeting (toxic dinoflagellates - with published abstract)  
 Microbiology Society of NC - annual meeting, Research Triangle Park: Keynote Speaker (*Pfiesteria*, other toxic dinoflagellates)  
 NC Water Resources Association - Conference on Water Pollution Issues in NC, Asheville: Keynote Speaker (*Pfiesteria*, other toxic dinoflagellates - with published abstract)  
 Northeast Algal Symposium - annual meeting, Plymouth, MA – Keynote Speaker (toxic *Pfiesteria* - with published abstract)  
 American Society of Limnology and Oceanography - joint summer meeting with the Ecological Society of America, Symposium Session Honoring Minority Students: Keynote Speaker (*Pfiesteria*, other harmful algae – with published abstract)  
 Stanford University, Institute of Ecosystem Ecology (toxic *Pfiesteria*)  
 NASA, Goddard Space Center, Baltimore, MD (*Pfiesteria*, other toxic dinoflagellates)  
 Keynote Seminar Series in Marine Sciences, Wilmington, DE (sponsors, U DE, DE Sea Grant): Presentation (*Pfiesteria*)  
 Friends of the Library, NCSU (*Pfiesteria*, other toxic dinoflagellates)  
 Department of Biology, Auburn University (toxic dinoflagellates)  
 Department of Environmental Sciences, Drexel University, Philadelphia (toxic *Pfiesteria*)  
 Department of Biology, Hampden Sydney College, Hampden-Sydney, VA (toxic dinoflagellates)  
 Department of Biology, UNC Charlotte (*Pfiesteria*, other toxic dinoflagellates)  
 Headquarters, US EPA, Washington, DC (toxic *Pfiesteria*)  
 Distinguished Lecturer Series, Old Dominion University, Norfolk, VA (*Pfiesteria*)

### 1997

Society for Conservation Biology - annual meeting, Victoria, British Columbia, Canada (harmful algae and eutrophication - with published abstract)  
 Department of Biology, University at Buffalo, Buffalo, NY (*Pfiesteria*, other toxic dinoflagellates)  
 Departments of Zoology and Oceanography, OSU (toxic algae)  
 3<sup>rd</sup> Annual Conference on Population-Level Effects of Marine and Estuarine Contamination, Charleston, SC (science, policy - with published abstract)  
 Wagner College, Staten Island, NY (special college-wide seminar, toxic *Pfiesteria*)  
 Department of Biological Science, Florida State University, Tallahassee (toxic dinoflagellates)  
 Department of Botany, Duke University (*Pfiesteria*, other toxic dinoflagellates)  
 Conference on Fisheries, Habitat and Pollution (sponsors, SC Sea Grant, TerrAqua Environmental Science and Policy Institute), Charleston, SC (chronic and sublethal effects of harmful algae - with published abstract)  
 Institute of Ecosystem Studies, Millbrook, NY (chronic and sublethal effects)  
 American Fisheries Society, NC Chapter - annual meeting, Lake Wylie, SC (*Pfiesteria* - with published abstract)

### 1996

AAAS - annual meeting, session Global Change and Emerging Infectious Diseases (effects of harmful algae on fish and mammalian health - with published abstract)  
 NATO Workshop, Physiological Ecology of Harmful Marine Phytoplankton, Bermuda Biological Station for Research (raptorial dinoflagellates - with published abstract)  
 Sigma Xi - UNC Greensboro and NCCU Chapters: Keynote Speaker (toxic *Pfiesteria*)  
 Department of Biology, Southampton College, Long Island University, Southampton, NY (toxic dinoflagellates)

Department of Biology, University of Cincinnati, Cincinnati (toxic dinoflagellates)  
NIEHS, Research Triangle Park (toxic *Pfiesteria*)  
Whitney Laboratory, U FL - St. Augustine (toxic dinoflagellates)  
Department of Biology, Wake Forest University, Winston-Salem (toxic dinoflagellates)  
Association of Women in Science, UNC Chapel Hill (*Pfiesteria*, other toxic dinoflagellates)  
Texas A & M University, Corpus Christi, TX (*Pfiesteria*, other toxic dinoflagellates)

#### 1995

Society of Protozoologists - annual meeting, U AL, Tuscaloosa, AL: Keynote Speaker (toxic *Pfiesteria* and its microbial, macroinvertebrate and vertebrate prey - with published abstract)  
5<sup>th</sup> Pan American Symposium on Animal, Plant and Microbial Toxins, Baltimore, MD (*Pfiesteria* - with published abstract)  
Department of Toxicology, NCSU (toxic dinoflagellates)  
Department of Biology, U MD, Baltimore, MD (toxic *Pfiesteria*)

#### 1994

First International Conference on Ecosystem Health and Medicine, Ottawa, Ontario, Canada (effects on human health - with published abstract)  
E-MAP Monitoring Program, US EPA, Research Triangle Park (emerging toxic algae - effects on fisheries and public health)  
Department of Biology, University of Richmond (emerging toxic algae)  
Department of Environmental Health, Boston University (toxic dinoflagellates)  
Department of Biology, SUNY - Stony Brook (toxic dinoflagellates)  
International Society for Evolutionary Protistology - Biennial Meeting, Halifax, Nova Scotia, Canada: Keynote Speaker (*Pfiesteria* and its prey - with published abstract)  
Institute of Ecology, U GA - Athens (harmful heterotrophic dinoflagellates)  
Department of Fisheries and Aquaculture, U FL - Gainesville (toxic dinoflagellates)

#### 1993

Fifth International Conference on Modern and Fossil Dinoflagellates (Zeist, the Netherlands): Keynote Speaker (toxic *Pfiesteria* - with published abstract)  
Beta Beta Beta Biological Honors Society, Elon University: Keynote Speaker (effects of toxic *Pfiesteria* on estuarine food webs)  
Chesapeake Biological Laboratory, Solomons, MD (toxic dinoflagellates)  
Southeastern Fisheries Society, Reidsville, NC (toxic dinoflagellates and fish health)  
Dauphin Island Marine Laboratory, Dauphin Island, AL (toxic dinoflagellates)  
Department of MEAS, NCSU (*Pfiesteria*)

#### 1992

V<sup>th</sup> International Symposium on Toxic Algae, Newport, RI (toxic *Pfiesteria* - with published abstract)  
Southeast Regional Directors of the Sea Grant College Program - annual meeting: Keynote Speaker (*Pfiesteria*)  
Department of Zoology, NCSU (toxic *Pfiesteria*)  
US Geological Survey, Raleigh (toxic *Pfiesteria*)  
NC Statewide Phytoplankton Meeting, Duke Power Company (Huntersville, NC: Keynote Speaker)  
Department of Biology, UNC Wilmington (*Pfiesteria*, other toxic dinoflagellates)  
Department of Biology, Appalachian State University, Boone, NC (toxic dinoflagellates)  
Department of Biology, UNC Greensboro (toxic dinoflagellates)  
US EPA, Narragansett, RI (*Pfiesteria*, other toxic dinoflagellates)  
Department of Biology - Marine Sciences Group, UNC Chapel Hill (toxic dinoflagellates)  
Bodega Marine Laboratory, U CA - Davis, Bodega Bay (toxic dinoflagellates)

## ***Other Algae***

2012

Phycological Society of America, Charleston, SC (Mixson, S. and J. Burkholder - enhancing lipid production in the marine microalga *Dunaliella* through environmental stressors - with published abstract)

2010

Webinar, Northwestern University special summer course for graduate students, given at the University of British Columbia, Vancouver, BC (the ecology of periphyton)

2007

Society of International Limnologists (SIL) - 30<sup>th</sup> Congress of the International Association of Theoretical and Applied Limnology, Montreal, Quebec, Canada (importance of benthic microalgae across freshwater, estuarine and marine ecosystems - with published abstract)

1999

Society for General Microbiology - Symposium, Microbial Signaling and Communication, University of Edinburgh, Edinburgh, Scotland (signaling in dinoflagellates - with published abstract)

1991

Department of Biology, VPI, Blacksburg, VA (phytoplankton survival of pulsed suspended sediment loading)

1990

Center for Reservoir Research, Hancock Biological Station, Murray State University, Paducah, KY (phytoplankton and periphyton dynamics in turbid, eutrophic reservoirs)  
Department of Zoology, NCSU - Aquatic Ecology Seminar Series (mutualistic symbioses involving algae)  
Department of MEAS, NCSU (role of benthic microalgae in eutrophication of freshwater and coastal marine habitats)

1989

Experimental Lakes Area (ELA), University of Manitoba, Winnipeg, Manitoba, Canada (relative importance of the water column and macrophytes as nutrient sources for epiphytes)  
Hampton University, Hampton, VA (biotechnology in aquatic ecology)  
Department of Biology, University of Louisville, Louisville, KY (use of autoradiography to examine nutrient dynamics of microalgal biofilms)  
Duke Marine Laboratory, Beaufort (nutrients and epiphytes – unifying trends in freshwater and marine ecosystems)

1988

Department of Biology, UNC Chapel Hill - Marine Macroalgae Seminar Series (epiphytes)  
Department of Biology, East Carolina University (phosphorus sources for epiphytic microalgae)  
Department of Botany, Duke University (nutrient sources for epiphytic microalgae)  
Environmental Section, Carolina Power and Light Company, New Hill, NC (epiphytic microalgae - role in nutrient cycling of lakes)

## ***Science Ethics and Environmental Issues***

2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014

Park Scholars Program, NCSU (role of science ethics in environmental issues)

2005

Department of Epidemiology, UNC Chapel Hill, Forum “Funding, Academic Freedom, and Public Responsibility” (industry and water quality)

## 2004

Department of Biology, Cornell University (toxic algae)

Department of Civil Engineering, NCSU (water quality)

Department of Biology, UNC Asheville (water quality)

## 2003

New York Metropolitan Association of College and University Biologists – 36<sup>th</sup> Annual Conference,

Wagner College, Staten Island: Keynote address (role of science ethics in natural resource issues)

NSF Environmental Education Program, NCSU (toxic algae, water quality)

## 1999

Department of Geology, University of Oslo, Oslo, Norway (toxic algae, water quality)

Park Foundation Lecture Series, College of Journalism, UNC Chapel Hill (critical role of journalists in environmental science education and ethics)

## 1998

Metcalf Institute for Marine and Environmental Journalism - annual board meeting, URI: Keynote

Speaker (how environmental journalists can help to strengthen science ethics)

## **Academic Contributions**

### ***Courses Taught***

- PB 595A, *Aquatic Plant Ecology* (4 credits; 1987 - present, fall alternate years)
- PB 595W, *Environmental Issues in Aquatic Ecology* (3 credits, 1990 - present, usually fall alternate years) - special topics/current events graduate course
- PB/MB 774, *Phycology* (3 credits including laboratories; 1987 - present, spring alternate years)
- BO 595E, *Ecology, Evolution and Diversity* – (2003; course coordinator, Jon Stuckey); mini-course: designed and taught one of eight modules on aquatic vascular plants as bioinvaders
- PB 824C, *Plant Biology Colloquium* (1 credit) – co-taught with Nina Allen (spring 2002, 2004, 2006) or Bill Thompson (spring 2009, 2011, 2013); graduate students receive training to give presentations, write grant proposals, and critique grant proposals)
- HON 398, *Honors Seminar on Aquatic Ecology* (1 credit, spring 2008) – seminar/discussion course for undergraduate honors students on aquatic natural resource issues in North Carolina
- EMS 496/622/822 or TDE 490/610 – STEM Education Seminar Course, *Environmental Issues in Estuarine Ecology and Pedagogical Applications* (1 credit, spring 2010), co-taught with P. Simmons and A. Clark.

### ***Guest Lectures*** (examples, past five years)

- PB 101, *Introduction to Plant Biology*, Department of Plant Biology, NCSU (once per year, 2006-2011)
- PB 250, *Plant Biology*, Department of Plant Biology, NCSU (2010, 2011, 2015)
- *Park Scholars*, NCSU (once per year, 2006-2014)
- Freshman Focus Program, “Science, Society, Uncertainty, and Conflicting Values” (Duke University, Durham, NC, 2010)

### ***Major or Co-major Advisor of Graduate Students***

Stacie Flood, Ph.D. (Plant and Microbial Biology, in progress, expected spring 2016)



Nicole Lindor, Ph.D. (Plant and Microbial Biology, in progress, 2014-)

Stephanie Mixson, Ph.D. (Plant & Microbial Biology [department name change] - 2013)

Thesis: *Dunaliella* spp. under environmental stress: Enhancing lipid production and optimizing harvest  
Honor: Secured a grant to help support her dissertation research, from the Charles A. and Anne Morrow Lindbergh Foundation (2010)

Post-Graduate Position: Analytical Development Specialist, Medicago USA, Research Triangle Park (2013)

Eva Ngulo, M.A. (Plant Biology, 2011)

Final paper: Influence of clay treatment on noxious planktonic cyanobacteria

Kimberly Null, Ph.D. (MEAS; co-advisor with Dr. Dave DeMaster), 2010

Thesis: Ammonium dynamics in a shallow lagoonal estuary

Honors: Secured two grants to help support her dissertation research, from the NC Academy of Science (2006) and the Geological Society of America (2006)

Post-Graduate Positions: Post-Doctoral Research Associate, University of California - Santa Cruz, then Post-Doctoral Research Associate, East Carolina University - Greenville, NC (research in Antarctica)

Hayley Skelton, Ph.D. (MEAS; co-advisor, Dr. Dan Kamykowski), 2008

Thesis: Nutritional features and feeding behavior of the heterotrophic dinoflagellate, *Pfiesteria shumwayae*

Honor: Won the Theodore L. Jahn and Eugene C. Bovee Award for best graduate student research paper, annual meeting of the International Society of Protozoologists, Providence, RI (2007)

Post-Graduate Positions: Post-Doctoral Fellow, National Research Council, NOAA / University of Connecticut (2008), then Supervisor of Algal Culturing, Algenol Biofuels, Fort Myers, FL (2009)

Meghan Rothenberger, Ph.D. (Plant Biology), 2007

Thesis: Long-term impacts of changing land use practices on water quality and phytoplankton assemblages in the Neuse Estuary ecosystem, North Carolina

Honors: Won best graduate research presentation, Graduate Student Forum, Department of Plant Biology (2007)  
Won best Ph.D. dissertation of the year (2007) at NCSU, from the NCSU Graduate School (2008)

Post-Graduate Positions: Post-Doctoral Associate, CAAE (Visiting Professor, UNC Greensboro; then assistant professor at Lafayette College, Easton, PA)

Susan Pate, M.Sc. (Botany), 2006

Thesis: Impacts of the toxic dinoflagellate *Alexandrium monilatum* on three ecologically important shellfish species

Post-Graduate Position: Laboratory Administrator (Biotechnology), Duke University

Matthew Parrow, Ph.D. (Botany), 2003

Thesis: Feeding, reproduction, and sexuality in *Pfiesteria* spp. and cryptoperidiniopsoid estuarine heterotrophic dinoflagellates

Honor: Won the Kellar Award for outstanding dissertation research (NCSU), 2004

Post-Graduate Positions: Post-Doctoral Associate, CAAE (now Assistant Professor, UNC Charlotte)

Paul Cancellieri, M.Sc. (Botany), 2001

Thesis: Chemosensory attraction of *Pfiesteria* spp. to fish secretions

Post-Graduate Position: Teacher, Durant Middle School, Raleigh

Howard Glasgow, Ph.D. (MEAS; co-advisor; main advisor, Dr. Dan Kamykowski), 2000

Thesis: Biology and impacts of toxic *Pfiesteria* complex species

Post-Graduate Position: Researcher, CAAE (permanently disabled by a neurological illness)

Jeffrey Springer, M.Sc. (MEAS; co-advisor, Dr. Dave Eggleston), 2000

Thesis: Interactions between two commercially important species of bivalve molluscs and the toxic estuarine dinoflagellate, *Pfiesteria piscicida*

Honor: Won the Best Student Presentation Award at the Annual Meeting of the National Shellfish Association, Seattle, WA, 2002

Post-Graduate Position: Research Associate, CAAE

Naomi Tsurumi, M.A. (Botany), 2000 Thesis: Influence of Industrialized Swine Agriculture on Air Quality

Post-Graduate Position: Environmental Policy M.A. program, Duke University

Brant Touchette, Ph.D. (Botany), 1999

Thesis: Physiological and developmental responses of eelgrass (*Zostera marina* L.) to increases in water-column nitrate and temperature

Post-Graduate Position: Assistant Professor, Elon University (now associate professor)

Elizabeth Fensin, M.Sc. (Botany), 1997

Thesis: Population dynamics of *Pfiesteria*-like dinoflagellates, and environmental controls in the mesohaline Neuse Estuary, North Carolina, USA

Post-Graduate Position: Research Assistant, North Carolina Department of Environment and Natural Resources (then called the NC Department of Environment, Health, and Natural Resources)

L. Michael Larsen, Ph.D. (Zoology; co-advisor with Dr. Sam Mosley), 1995

Thesis: Responses of *Diaphanosoma brachyurum* (Cladocera: Suicide) and other zooplankton to clay loading and algal food quality in a turbid southeastern reservoir.

Post-Graduate Position: Assistant Professor, Campbell University, Fayetteville, NC (now Professor and Department Chair, Biology)

Leslie (Taylor) Taggett, M.Sc. (Botany), 1995

Thesis: Nitrate reductase activity of two intertidal macroalgae across gradients of temperature, salinity and desiccation

Post-Graduate Position: Research Assistant – Analytical Chemistry Laboratory, NC DEHNR

Virginia Coleman, M.Sc. (Botany), 1993

Thesis: Community structure and productivity of epiphytic microalgae on eelgrass (*Zostera marina* L.) under water-column nitrate enrichment

Post-Graduate Position: Research Associate – Algal Laboratory, NC Department of Environment and Natural Resources

Phumelele Gama, M.S. (Botany), 1992

Thesis: Phytoplankton response to a sediment loading gradient in a mesotrophic reservoir

Post-Graduate Position: Lecturer of Botany, University of Zululand, South Africa

Deborah Everitt (Tan), M.S. (Botany), 1992

Thesis: Seasonal dynamics of macrophyte communities from a stream flowing over granite flatrock in North Carolina, USA

Post-Graduate Position: Stream Scientist, MD Department of Natural Resources

### **Other Graduate Student Committee Memberships**

**Ph.D**

Stephanie Archer, Applied Ecology

**Ph.D. (cont' d)** Yini Shangguan, U MD (Center for Environmental Science)  
 Brett Hartis, Fisheries, Wildlife and Conservation Biology  
 Geoff Sinclair, MEAS  
 Diane Whitaker, Science Education  
 Katherine Galucci, Science Education  
 Daniel Dickerson, Science Education  
 Nancy White, Forestry  
 Louis Elsing, Forestry  
 Dennis Hazel, Forestry  
 Gary Kirkpatrick, Zoology  
 Francois Bergand, Biological and Agricultural Engineering  
 Leslie Dorworth, MEAS  
 Thomas Shahady, Zoology  
 Randall Jackson, Zoology  
 Elise Irwin, Zoology  
 Kimberly Jones, Chemistry (UNC Wilmington)  
 George Hess, Biomathematics  
 Ann Darrien, Zoology  
 Elizabeth Marschall, Zoology

**M.Sc.** Susan Randolph, Science Education  
 John Grady, Plant Biology  
 Carolyn Foley, Botany  
 Chad Coley, Soil Science  
 Angela Poovey, Crop and Soil Science  
 Scott Thomas, Biological and Agricultural Engineering  
 Kristin Toffer, Biology, UNC Greensboro  
 Beth Buffington, Crop and Soil Science  
 Edward Walycz, MEAS  
 Lisa Hartley, Botany  
 Robert Clark, Zoology  
 Beth Walker, Zoology  
 Rose Ragnacci, MEAS  
 Karen Kracko, Zoology

***Postdoctoral Associate Advisor***

Meghan Rothenberger, 2007: Present position, Assistant Professor, Lafayette College  
 Matthew Parrow, 2004-2006: Present position, Assistant Professor, UNC Charlotte  
 Brant Touchette, 2000-2002: Present position, Associate Professor, Elon University  
 Cheng Zhang, 1999-2003: Present position, Research Scientist, North Carolina Department of Environment and Natural Resources

***Visiting Fulbright Scholar***

Allasanne Ouattara, Ivory Coast, 2008-2009: Professor from the University of Abobo-Adjamé

**Activities in Other Academic Programs**

***Kenan Fellows Program*** (for gifted K-12 teachers)

Mentor to Amanda Warren  
 Mentor to Susan Randolph  
 Mentor to Diane Whittaker

Secondary mentor to Gayle Powell  
Panelist on selection committee for Kenan Fellows

### ***Other NC State Service***

Member, Big Ideas Committee (college)  
Member, CALS Innovation and Efficiency Committee (college)  
Member, William Neal Reynolds Distinguished Professor Selection Committee (college)  
Member, College of Agriculture and Life Sciences Research Committee (college)  
Member, Advisory Committee, Applied Ecology (departmental)  
Member, Advisory Committee, Plant Biology (departmental)  
Chair, Plant Biology Post-Tenure Evaluation Committee (departmental)  
Member, Selection Committee for Evolutionary Ecologist Position (departmental)  
Member, Larry A. Whitford Botany Scholarship/Fellowship Award Committee (departmental)  
Member, Plant Biology Mentoring Committee for Alexander Krings (departmental)  
Member, Plant Biology Mentoring Committee for Bill Hoffmann (departmental)  
Member, Plant Biology Undergraduate Curriculum Committee (departmental)  
Member, Search Committee, Plant Biology - Evolutionary Ecologist (departmental)  
Member, Water Quality Committee (university)  
Member, Water Resources Curriculum Committee (university)  
Member, Ad Hoc Committee on Marine Science (university)  
Member, Advisory Committee for the NCSU publication, *Results: Research and Innovation at North Carolina State University* (university)

### **Education Outreach** (examples, past five years)

#### ***K-12 Students and Teachers***

The CAAE's *Floating Classroom Program* aboard our research/education ship, *RV Humphries*: Provided hands-on education in aquatic science (1/2-day cruise on the Neuse Estuary for 278 8<sup>th</sup> graders and their teachers (2014), 345 9<sup>th</sup> graders and their teachers (2013), 360 9<sup>th</sup> graders and their teachers (2012), and 480 9<sup>th</sup> graders and their teachers (2011) from Wayne County schools in economically depressed areas Guilford Co. high school teachers' training – presentation to ~30 teachers on designing experiments, 2011 Cardinal Gibbons High School, Cary, NC – presentation to ~80 students on water quality issues nationally and in our State (senior-level courses, *Ecology* and *Environmental Issues*), 2010

#### ***General Citizenry***

Good Shepherd United Church of Christ, Cary, NC, March 2015 (Anne Mackie)  
Status of Drinking Water Quality and Protection in North Carolina (League of Women Voters), 2014  
Forum on Status of the Neuse Estuary and Industrialized Swine Production (presentation to Coastal River Watch), 2013  
Water Quality in High Rock Lake (presentation to the Yadkin Riverkeeper Foundation), 2013  
Status of Water Quality in Falls Lake (presentation to the concerned citizens group, Wake Up Wake County), 2010

**Other Service** - Member, City of Raleigh Stormwater Commission, 2010-present

**Society Memberships** - AAAS, Association for the Sciences of Limnology and Oceanography, Coastal and Estuarine Research Federation, North American Lake Management Society, Phi Kappa Phi, Phycological Society of America, Sigma Xi