Ecological Indicators of Effects of Changing Air Quality

Christine Negra and Robin O'Malley, *The Heinz Center*

In partnership with EPA
Clean Air Markets Division

National Atmospheric Deposition Program
October 16, 2008

Air quality managers need scientific tools for:

- tracking air pollution induced ecological impairment
- documenting the effectiveness of air pollution control strategies at protecting ecosystems

While some impacts are relatively well-documented, many ecosystem responses to airborne pollutants are not comprehensively monitored.

Project goals

Through a multi-stakeholder approach, identify strongly established inks between ecosystem exposure and response.

Develop a set of indicator metrics to inform environmental data collection and assessment of ecosystem response to changing air quality.

Methods I: Expert Advisors

Through 3 workshops, 30 experts from public and private institutions evaluated:

(1)metrics of ecological condition and exposure

(2)opportunities to strengthen quantitative links between metrics of exposure and ecological response.

Advisors

Praveen Amar, NESCAUM
Richard Artz, NOAA-ARL
Richard Ayres, Ayres Law Group
Jill Baron, USGS
Tamara Blett, NPS
Kent Burkey, USDA-ARS
Kevin Civerolo, NY-DEC
Ellis Cowling, NC State Univ.
Marion Deerhake, RTI International
Emily Elliott, U, of Pittsburgh
Dave Evers, BioDiversity Research Instit.
Ben Felzer, Marine Biological Laboratory
Mark Fenn, USFS
Mark Garrison, ERM
Patricia Glibert, U. of Maryland
Robert Goldstein, EPRI
Reed Harris, Tetra Tech Inc.
Robert Howarth, Cornell Univ.
Tom Jorling, International Paper/NEON
Christopher Knightes, EPA-NERL
Sagar Krupa, U. of Minnesota
Manuel Lerdau, U. Virginia
Jason Lynch, EPA-CAMD
Rob Mason, U. of Connecticut
Steve McNulty, USFS
Ron Neilson, USFS
Joe Rudek, Environmental Defense Fund
Richard Smith, USGS
Mark Southerland, Versar, Inc. ESM
Jill Webster, US FWS

Categorizing Ecological Endpoints

Reviewed 30+ ecological effects in 11 major ecosystem types*:

1. Well-studied ecological effects – relevant indicator metrics can be identified through literature review

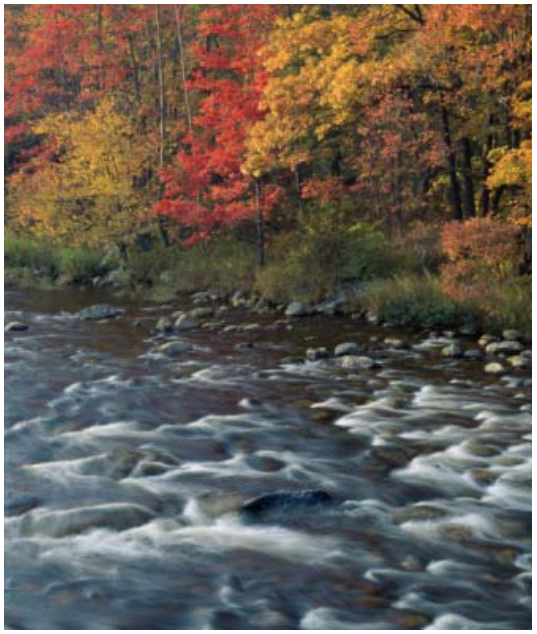
2. Ecological effects that need additional analysis to produce indicator metric

3. Ecological effects in need of substantial additional study – research base not broad enough for indicator development

* Alpine tundra, coniferous forests, deciduous forests, croplands, grass/ shrublands, streams, lakes, wetlands, estuaries, coastal waters, urbanized areas

Ecological Effects		Lit review to identify best metric	Possible customized analysis	*Research Needs* in report
NITROGEN AND SULFUR DEPOSITION				
Acidification	**Terrestrial**	Change in base cation status in forest soils (e.g., base saturation; BC:Al ratio)		Change in relative productivity, acid-sensitive biota
		Change in forest soil pH		
	Freshwater	Change in ANC in streams, lakes, ponds		Change in relative productivity, acid-sensitive biota
		Change in sulfate in streams, lakes, ponds		
Nitrogen enrichment	**Terrestrial**	Change in C:N ratio in soil organic matter	Change in community structure (lichen abundance or chemical composition; grass species dominance)	Altered chemical cycles (N uptake; N volatilization; relative net nitrification; litter decomposition/accumulation)
		Change in foliar N:P ratio or or N:productivity		Alteration of N-sensitive species/features, seedling root:shoot ratio, ratio of nitrophilic/phobic species, mycorrhizae, etc.
		Change in streamwater nitrogen status (e.g., nitrate, total nitrogen, N:P ratio; DIN:Total P ratio, DON:DIN ratio)		Altered disturbance regimes, e.g., hydrology, fire frequency (with change in species mix); pest outbreaks; invasive species
				Change in species composition (red:sugar maple ratio; fungil:bacteria ratio; hetero:autotrophic nitrifiers)
	Freshwater		Change in community structure (diatoms)	Change in species composition, abundance (nitrophilous algae; fish)
	Coastal systems		Change in total nitrogen	
			Change in dissolved oxygen	
			Change in Chlorophyll a (abundance, timing)	
AMBIENT OZONE				
Plant injury	**Terrestrial**	Foliar injury (e.g., lesions, leaf senescence) in forests, croplands and grass/shrublands	Change in plant physiology, e.g., yield (cropped systems); chlorophyll/water use efficiency in forests (spectral 'red shift')	
			Changes in species composition (ozone-sensitive species in forests)	
MERCURY DEPOSITION				
Methylation	**Aquatic**	Change in MeHg:Total Hg ratio in wetlands		Change in MeHg:Total Hg ratio in streams, coastal systems
Bioaccumulation	**Terrestrial**			Change in total Hg in tissues (blood/egg) of invertivores
	Aquatic	Change in MeHg in young-of-the-year fish tissues		
		Change in total Hg in tissues of piscivores (mature fish)		

Indicators to be designed for…



- Ozone-induced plant damage
- Methylmercury accumulation in food webs
- Acidification in terrestrial and freshwater ecosystems
- Nitrogen enrichment in terrestrial, freshwater and coastal systems

Cross-cutting indicator issues

- Should be sensitive over management-relevant timeframes and also relate to majority of affected ecosystems.
- Ecological sensitivity to air pollution is spatially variable.
- Spatially stratify indicator metrics by factors of ecological sensitivity and rates of pollutant transfer or transformation.

Cross-cutting issues (cont.)

- Exposure may vary seasonally or interannually.
- Effects may be acute or chronic.
- Loading to aquatic systems may represent contemporary or historical air emissions.
- Lag time between changes in air quality and changes in ecosystems.
- Indicators should account for temporal variability

Cross-cutting issues (cont.)

- Climate change, disturbance patterns and management activities affect ecosystems and can obscure or amplify signals of air pollution effects.
- Indicators should enable users to parse out ecological responses to changes in air quality.

Methods II: Literature review

For ecological endpoints with a robust, national-scale research base:

- Literature review to develop indicator metrics
  - Reviewed >180 journal articles and reports
- Integrate findings with advisors' recommendations

Ozone-induced foliar injury in forests

- Explore stratification of USFS biosite index data by:
  - Ozone exposure – more foliar injury expected at sites with higher ozone exposure
  - Plant available moisture – less foliar injury expected at water-limited sites – stomata restrict O_3 uptake
    - ***drought may explain the absence of foliar damage at sites where ozone exposure is high***
- Develop reporting categories that provide greater resolution, such as:

High ozone, moist **Low ozone, moist**

High ozone, dry **Low ozone, dry**

Ozone-induced change in crop growth/yield

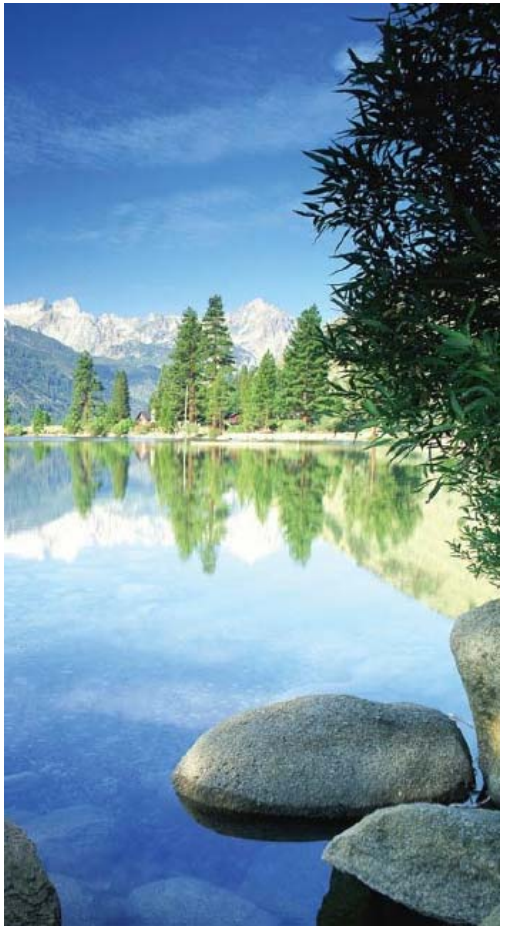
- Explore stratification of national datasets for crop growth/yield by:
  - Ozone exposure – lower productivity expected at sites where ozone exposure is higher
  - Crop cultivar – changing ozone sensitivity across cultivars may confound detection of trends
- Filter out drought-affected crops:
  - stomata restrict O_3 uptake – smaller effect of O_3 on growth/yield

Mercury bioaccumulation

- Develop geographically stratified reporting categories based on factors of mercury sensitivity, such as:
  - pH, DOC, S, ANC, wetlands
  - %MeHg as predictor of response time
- Freshwater: young-of-the-year (YOY) fish
  - Can stratification scheme could work for mature fish and/or piscivorous birds?
- Terrestrial (insectivores): Can we relate songbird Hg levels with specific geographic areas?

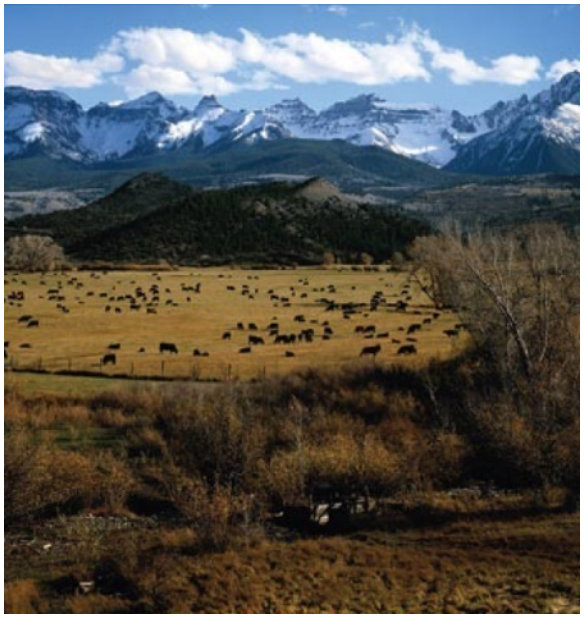
Soil and water acidification

- Develop stratified reporting categories based on sensitivity to acid deposition, such as:
  - pH; C:N ratio
- Soil base cation saturation or Ca:Al ratio
- Freshwater Acid Neutralizing Capacity
  - Possible threshold values



Nitrogen enrichment

- Develop stratified reporting categories based on sensitivity to nitrogen loading, such as:
  - C:N ratio, land cover, land use
- Nitrogen levels in plant biomass
  - Confounding with climate variables?
- Streamwater nitrogen levels
  - Sampling: seasonality?
- Chemical/biological changes in coastal waters
  - Nitrogen, dissolved oxygen
  - Chlorophyll



Next Steps

Commissioned studies to develop stratified reporting strategies that account for heterogeneity in ecological response

Evaluation of existing monitoring systems that can support recommended indicator metrics.

Investigating Data Sources

Evaluation of existing monitoring systems that can support recommended indicator metrics.


www.heinzctr.org/ecosystems