Monitoring and Evaluation of an Aeration System to Increase Dissolved Oxygen Levels at an Impoundment in the Northern Great Plains

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Introduction

- Lakes and reservoirs support fishing industry, tourism, recreation
  - $42 billion spent on U.S. fishing activities in 2006 (U.S. Department of Interior et al. 2006)
- Water quality issues can negatively impact fish populations
  - Reduction in recreation, possible negative economic impacts
- In North Dakota (ND), one of the most common issues is oxygen depletion

Introduction

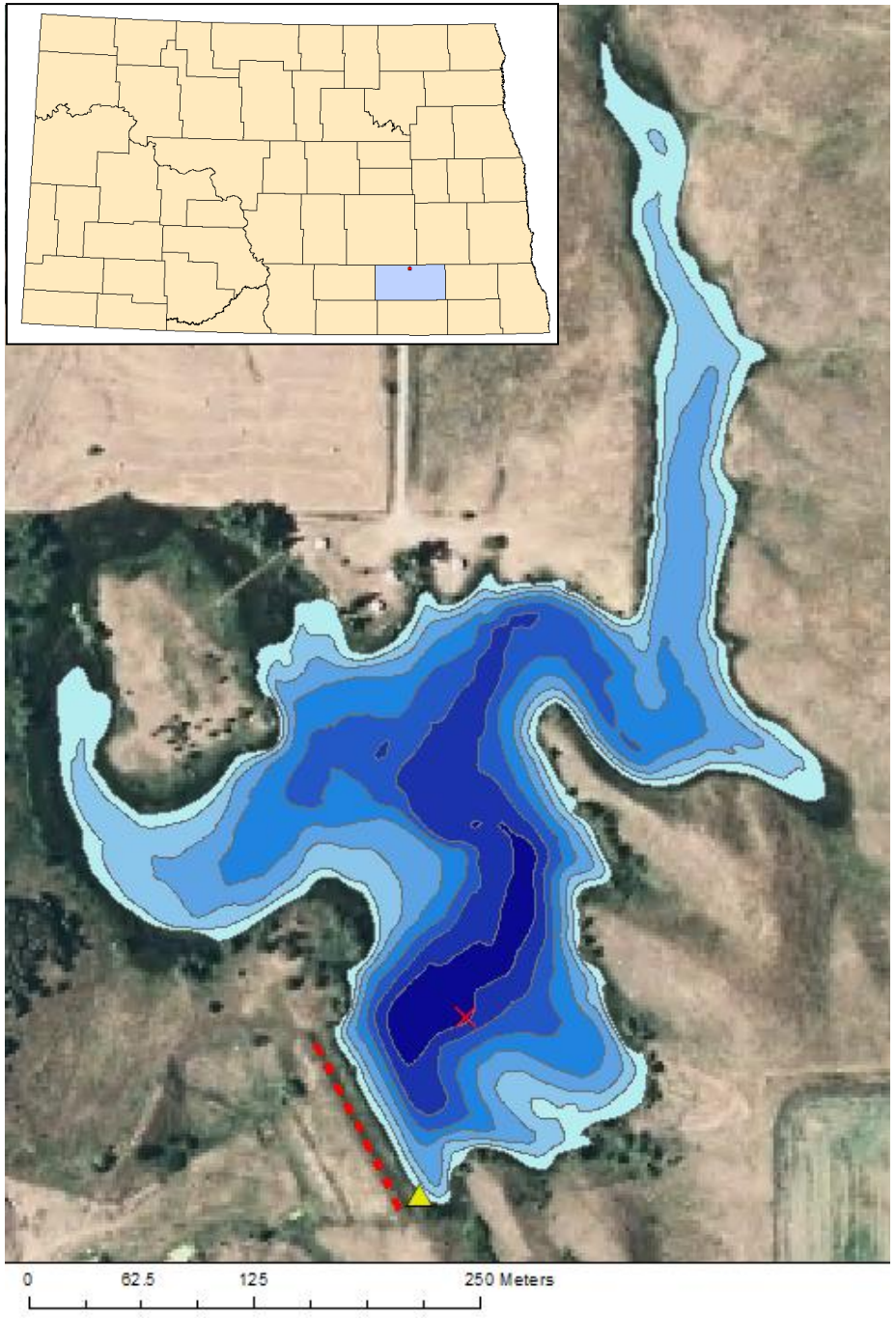
- Season changes, temperature and dissolved oxygen (DO) profiles change
- Thermal stratification
  - Surface layer (epilimnion) is well oxygenated
    - Wind mixing, algae
  - Bottom layer (hypolimnion) low DO
    - Decomposition of organic matter, lack of aeration
- North Dakota Game & Fish (NDGF) recorded low DO in Heinrich-Martin Dam (HMD) during summer months of 2002-2005
- Aeration system installed in 2006

Objectives

- The purpose of this study was to determine the short-term and long-term effectiveness of the aeration system and its impact on other water quality parameters
- Monitoring program designed and executed in 2008
  - To conduct on-site measurements to determine effectiveness of aeration for the entire impoundment
  - To analyze water and sediment samples to ascertain water quality variation and potential causes of DO depletion
  - To project quantitatively or qualitatively long term impact and effectiveness of aeration system based on analyzed samples

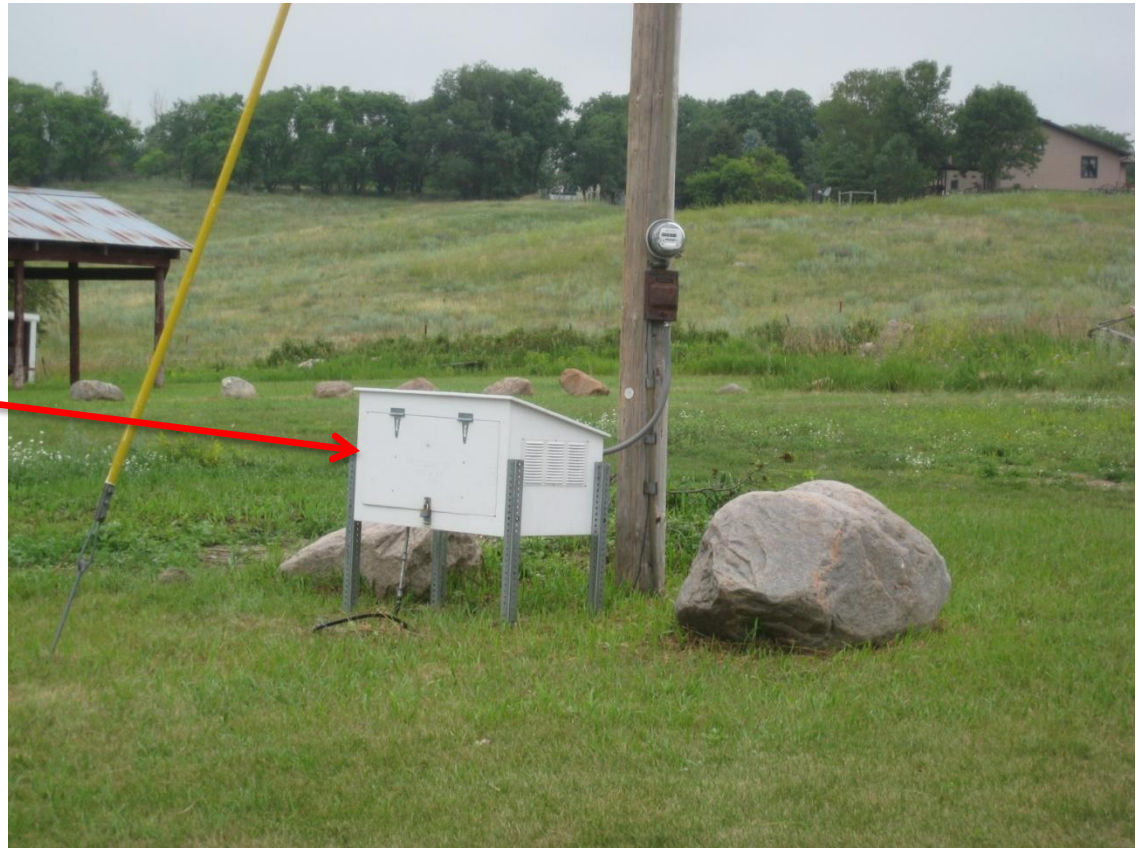
Materials & Methods

- Study Site
  - Located in LaMoure County, ND
  - Constructed in 1965
  - 0.08 km^2 (18.8 acre)
  - Earthen dam in SW corner
  - 1991- Water level controlled by overflow structure
  - Average water depth 4.3 m (14 ft.)
  - Maximum depth greater than 10.0 m (35 ft.)



Aeration System

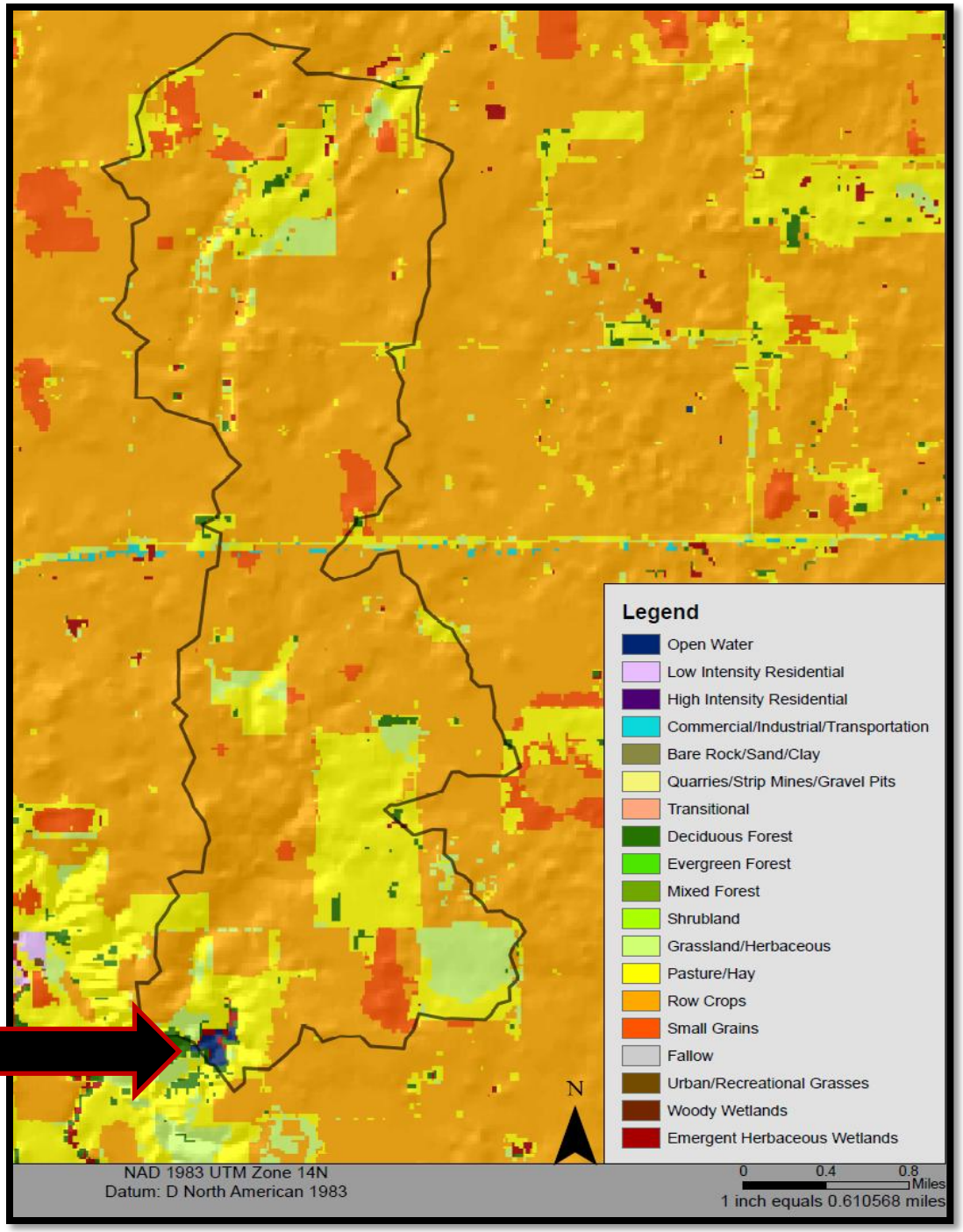
http://www.fws.gov/midwest/ashland/mtan_48.html



Land Use in the Drainage Basin

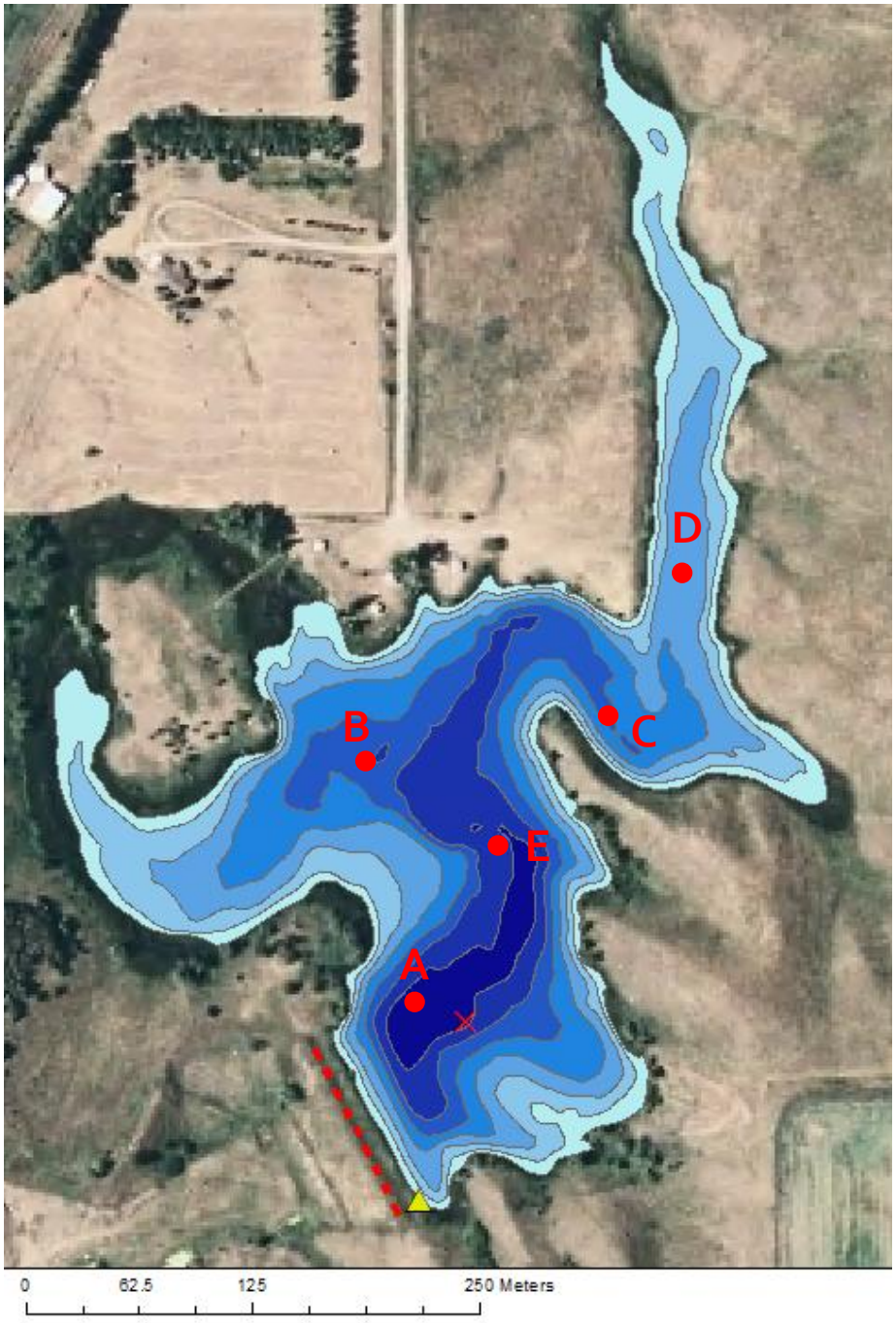
- Area of approximately 11.27 km^2 (7 $miles^2$)
- Major land use includes:
  - Pasture/Hay
  - Row Crops
  - Small Grains

Reservoir



Materials & Methods

- Field Sampling & Measurements
  - Five sampling locations
    - A
    - B
    - C and D
    - E
  - Sampling plan
    - May 22 – November 1
    - Aeration began June 20 and ended October 14

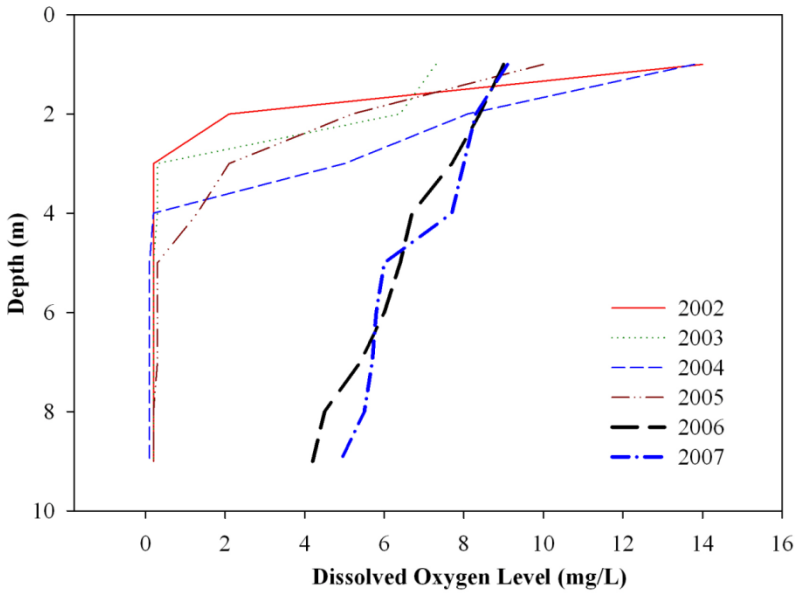


Materials & Methods

- On-site measurements
  - Air temperature, relative humidity, wind speed
  - DO, water temperature, specific conductance
  - Turbidity
- Water quality samples
  - North Dakota Department of Health: Environmental Lab
    - pH, major ions, nitrogen and phosphorus concentrations, alkalinity
- Sediment samples
  - Environmental Engineering Laboratory at NDSU
- 24-hour DO monitoring
  - August 17 to 18, 2008
  - DO and water temperature

Results & Discussion

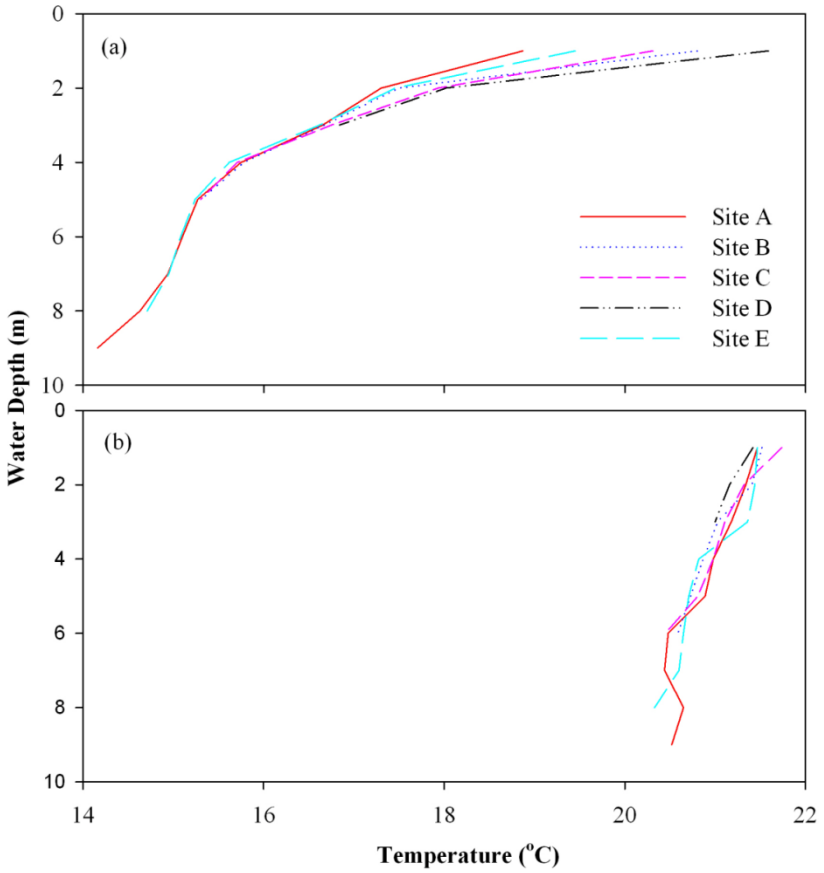
- Historic DO Level
  - Before aeration system installed, impoundment stratified and routinely exhibited anoxic conditions in hypolimnion during summer months
  - 2002-2005, DO profiles taken in deepest part (Site A) showed steep gradients from surface to depths >3m
    - Mid to late June, DO fell to <1 mg/L below a depth of 4m
  - Increase in DO observed since 2006 installation



Dissolved oxygen gradient at the deepest part (Site A) of the Heinrich-Martin Dam impoundment in late June or early July, while 2002-2005 with no aeration and 2006-2007 with aeration.

Results & Discussion

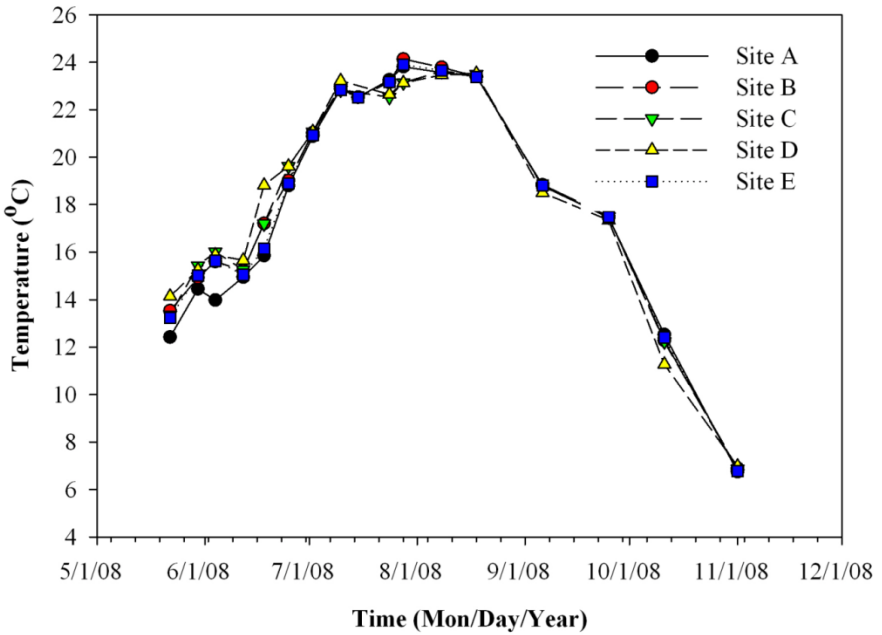
- Water Temperature Variations
  - Weak thermal stratification observed in May and June 2008 before aeration was started
  - After aeration began (June 20), destratification occurred within two weeks



Temperature profile at sampling site (a) collected on 18 June 2008, before aeration was turned on; and (b) on 2 July 2008 after aeration was started.

Results & Discussion

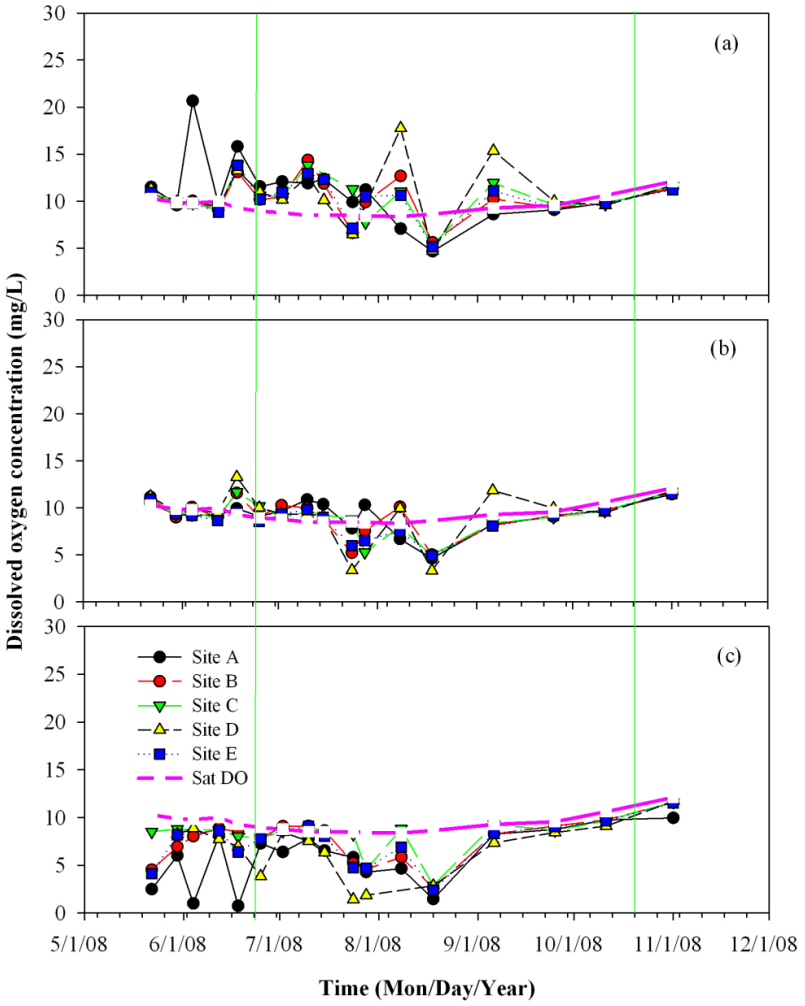
- Water Temperature Variations
  - After aeration started, no spatial temperature variation was observed among five sites
  - Water temperature increased steadily from late May to July
  - Remained stable (23±0.45°C) from mid-July to August
  - Gradually dropped after August 18



Average water temperature at Sites A, B, C, D, and E of Heinrich-Martin Dam Impoundment during 2008 sampling season.

Results & Discussion

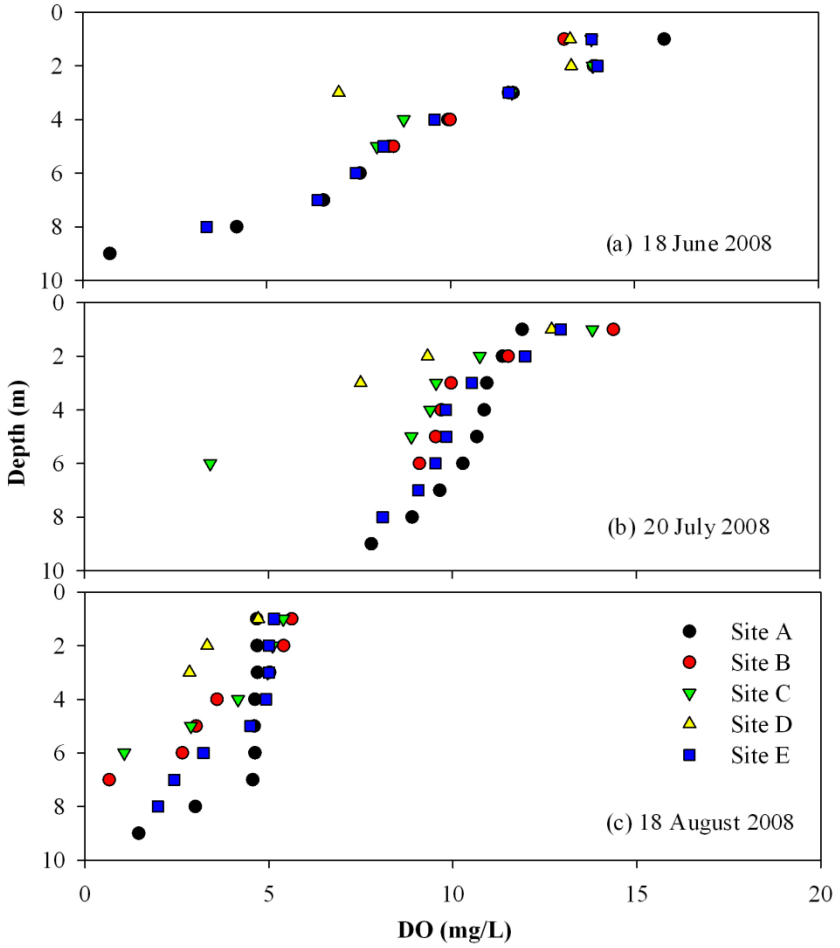
- Spatial & Temporal DO Variations
  - Surface layer high, near or over saturation
  - Mid-depth close to saturation at all sites
  - Bottom less than saturated with significant variation
    - After aeration, DO of bottom waters in Sites A,B,E increase and maintain >4 mg/L until mid-July
    - DO levels dropped at all sites from mid-July to late August
  - Decreasing trend throughout water depth may be the result of faster biological activities at high temperature and re-suspension of organic sediments by aeration
    - » Extensive algae growth
    - » High organic content of sediments ranging from 12.94% - 21.11%



Dissolved oxygen level at (a) surface, (b) midpoint, and (c) bottom layer of the impoundment at Site A, B, C, D, and E of Heinrich-Martin Dam in 2008, while the vertical green dashed lines indicate the start and end of the aeration system.

Results & Discussion

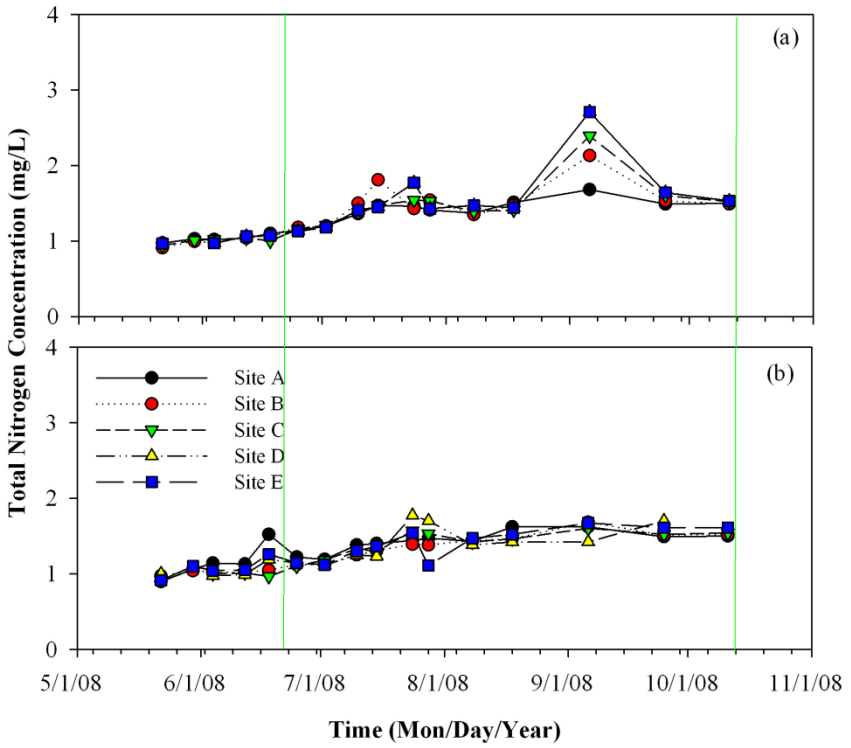
- Spatial and Temporal DO Variation
  - Before aeration (a) DO decreased sharply with water depth at all sites
  - 3 weeks after the start of aeration and elimination of thermal stratification DO profiles improved
  - Mid-August DO level close to 5 mg/L at surface and near zero at bottom



Dissolved oxygen concentration at all water depths for all sites (a) before aeration [18 June 2008), (b) three weeks into aeration [20 July 2008), and (c) late into aeration [18 August 2008).

Results & Discussion

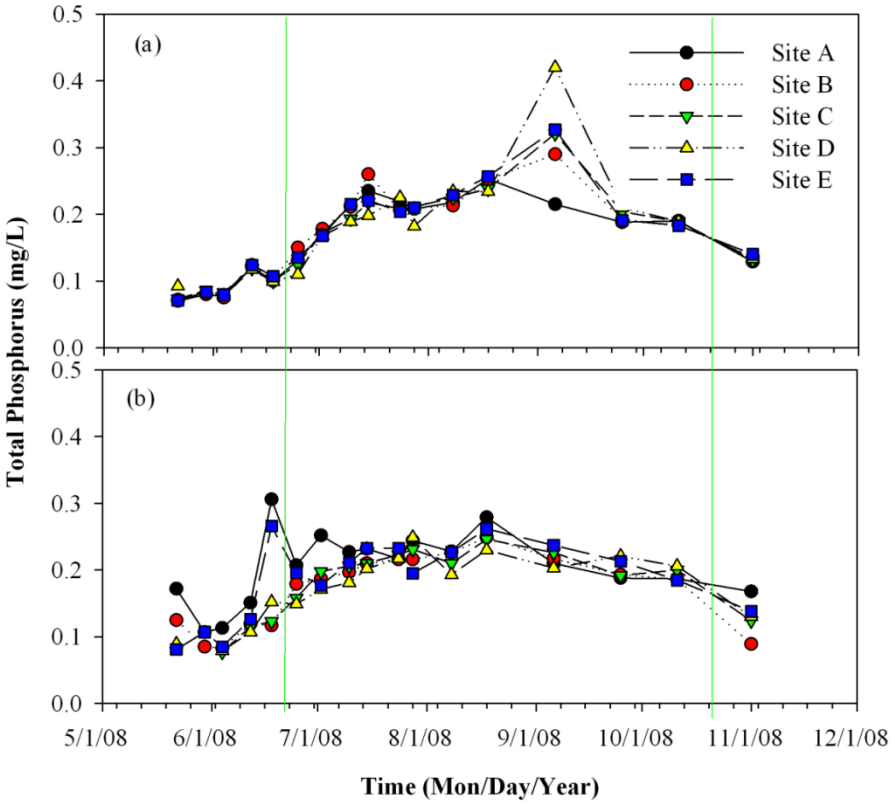
- Nutrient Measurements
- Total Nitrogen
  - 1.00-2.52 mg/L
  - Increased from May to August, peaked in September
  - Decreased when temperature began to drop and daylight hours shortened in mid-September
  - From analysis of different nitrogen forms, most nitrogen occurred as organic nitrogen
    - Agricultural runoff
    - Internal loading and release from sediment



Total nitrogen at (a) surface, and (b) bottom layer of the impoundment at Site A, B, C, D, and E of Heinrich-Martin Dam in 2008, while the vertical green dashed lines indicate the start and end of the aeration system.

Results & Discussion

- Nutrient Measurements
- Total Phosphorus
  - 0.07 – 0.42 mg/L
  - Steady increase at all sites
  - More significant compared to variation of Total N
  - Before aeration bottom (b) had higher total P
    - Indication of nutrient release from sediment
    - Anoxic conditions could affect phosphorus release
  - After aeration total P concentration are uniform



Total phosphorus at (a) surface, and (b) bottom layer of the impoundment at Site A, B, C, D, and E of Heinrich-Martin Dam in 2008, while the vertical green dashed lines indicate the start and end of the aeration system.

Conclusion

- Historical information (2002-2007) aeration was effective in increasing DO level to above 5 mg/L standard in the profundal zone (>4 m) around the deepest part of HMD where air diffusers were installed (NDGF)
- Aeration was effective in eliminating temperature stratification and resulted in improved DO concentration in the profundal zone in the entire impoundment.
- Results of water sample analyses showed that the impoundment was highly eutrophic with total nitrogen (TN) and total phosphorus (TP) concentrations greater than 1.0 mg/L and 0.1 mg/L, respectively.
- A 24-hour monitoring of DO showed clear diurnal DO changes at Sites A and E demonstrating the significant role of algae and aquatic plant growth on DO production and consumption.
- Analysis of sediment samples showed high organic matter contents. Decomposition of organic sediment likely caused the DO depletion in the profundal zone and release of nutrients. Mixing resulted from aeration may be effective in increasing DO levels, but it may also have made nutrients released from sediment available for algal growth making internal nutrient loading an important factor for algal bloom.
- Aeration may not be enough to maintain the level of DO necessary near the sediment-water interface to inhibit nutrient releases. Therefore, aeration alone is unlikely to provide long term improvements to the eutrophic status of the impoundment.

Acknowledgements

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