

Oxygen Dynamics in Lake Erie

Gerald Matisoff

Lake Erie Millennium Network
April 26-29, 2010



CASE WESTERN RESERVE
UNIVERSITY
EST. 1826

Oxygen Dynamics in Lake Erie

- * **Biogeochemical modeling of SOD, nutrient dynamics (Matisoff and Small)**
- * **Effects of mayflies, chironomids on SOD (Edwards, Soster, Matisoff and Schloesser, 2009)**
- * **Effects of storms, tributary flows (Conroy, Boegman, Zhang, Edwards, and Culver, ms)**
- * **ECOFORE (DePinto et al.)**

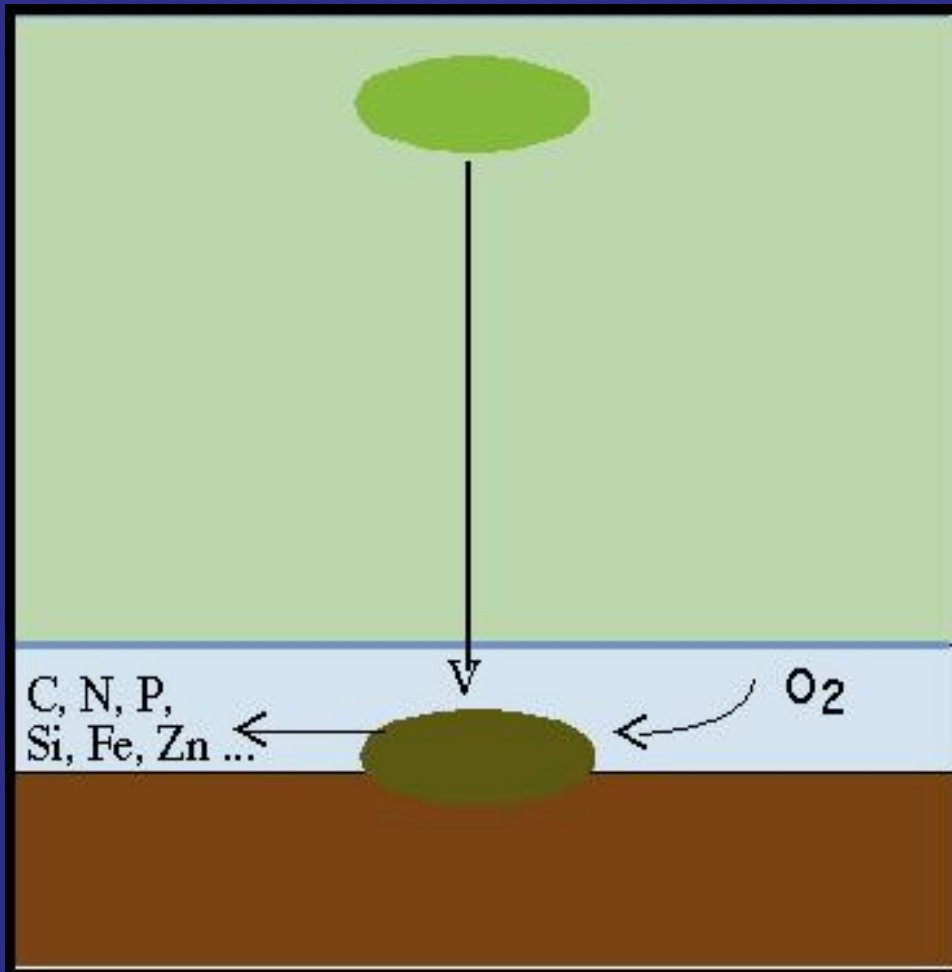
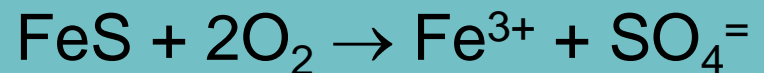
Biogeochemical Model for Organic Matter Oxidation

•Primary redox reactions (6)

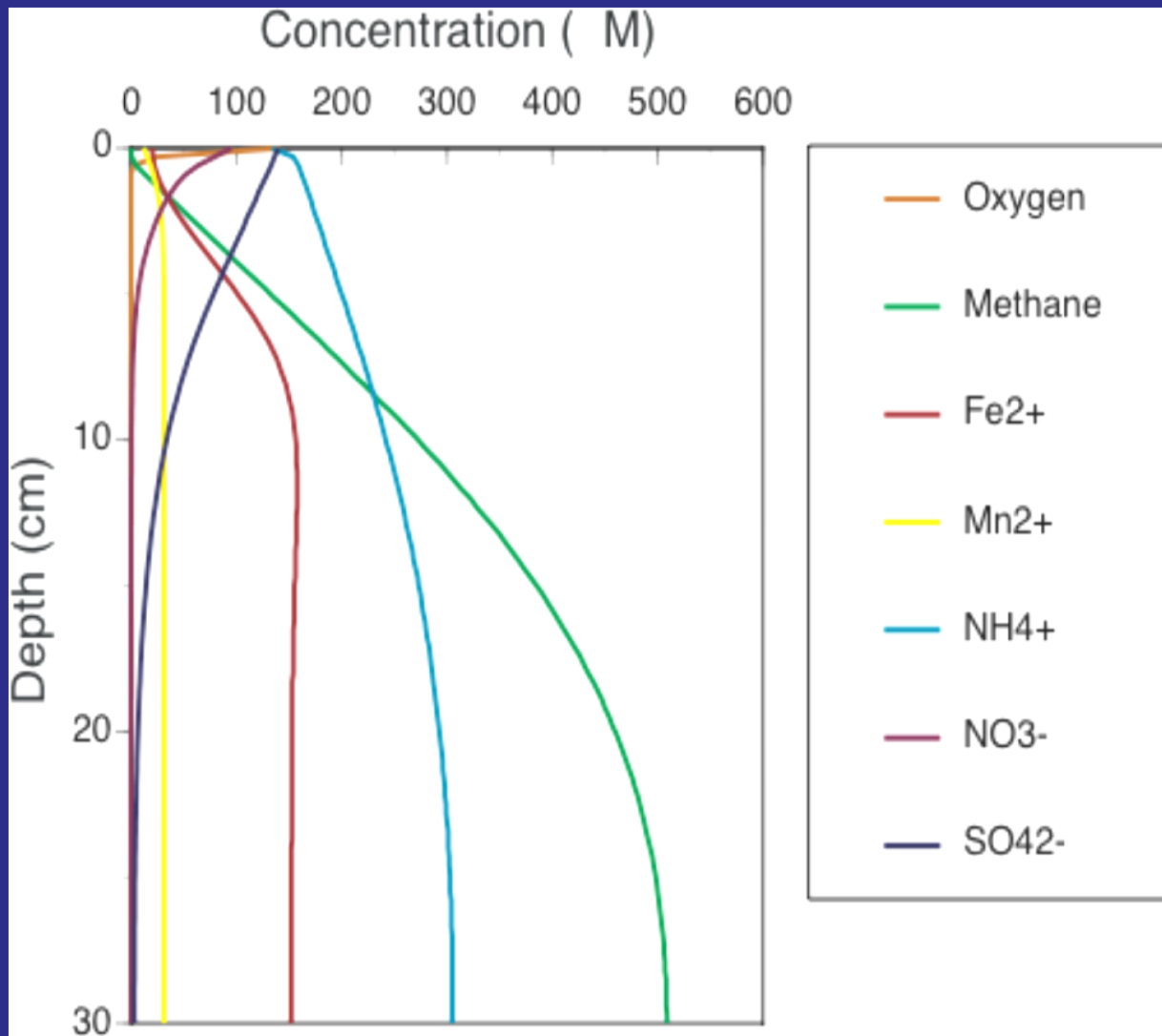
O_2	Aerobic respiration
NO_3^-	Nitrate reduction
MnO_2	Manganate reduction
$FeOOH$	Ferric reduction
SO_4^{2-}	Sulfate reduction
$CO_2 + CH_4$	Methane fermentation

•Secondary redox reactions (10)

Example:



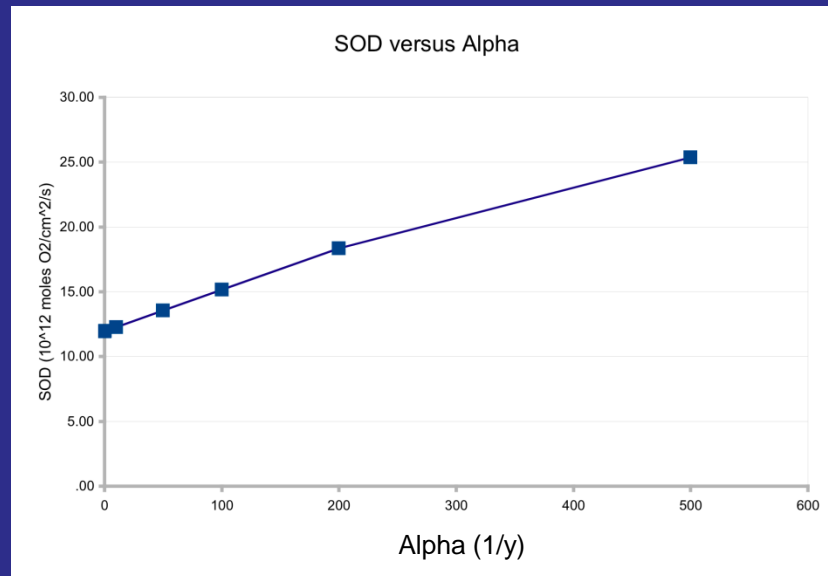
Model Results



Model Results

Process	% SOD
Aerobic respiration	48
Nitrification	0.7
Mn ²⁺ oxidation	12
Fe ²⁺ oxidation	26
Secondary reactions	small

Bioirrigation increases SOD ~2X



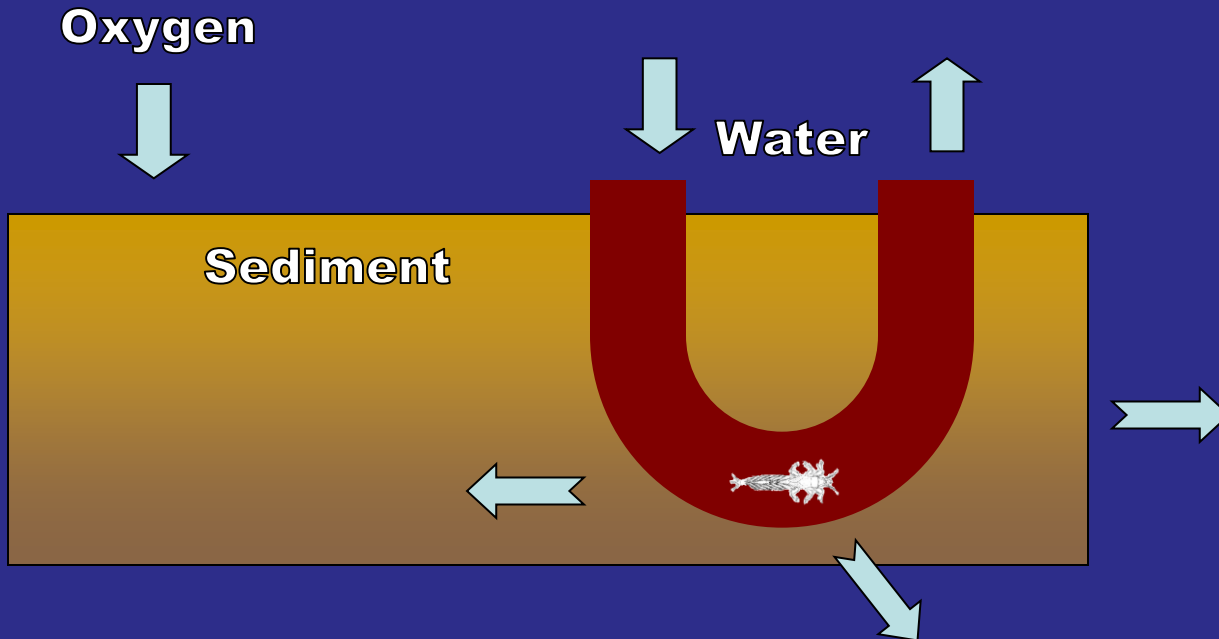
Effects of Bioirrigation on SOD



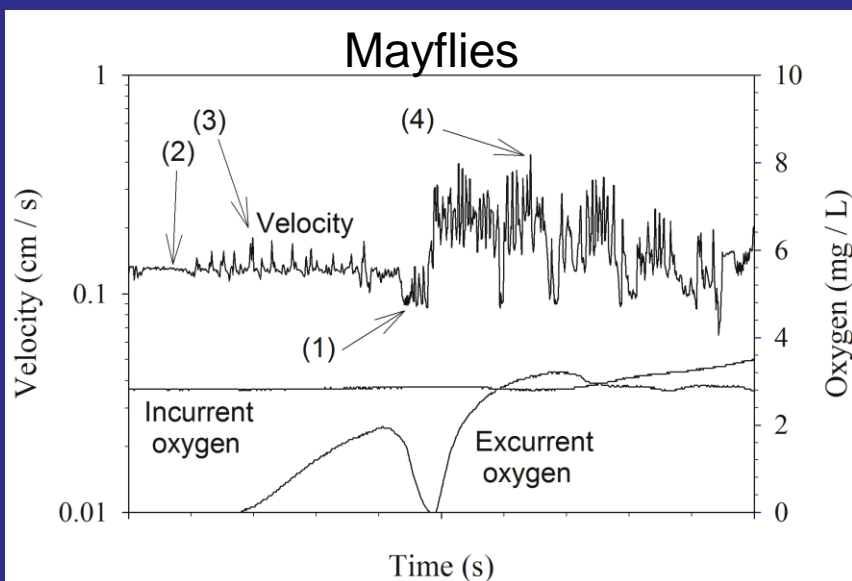
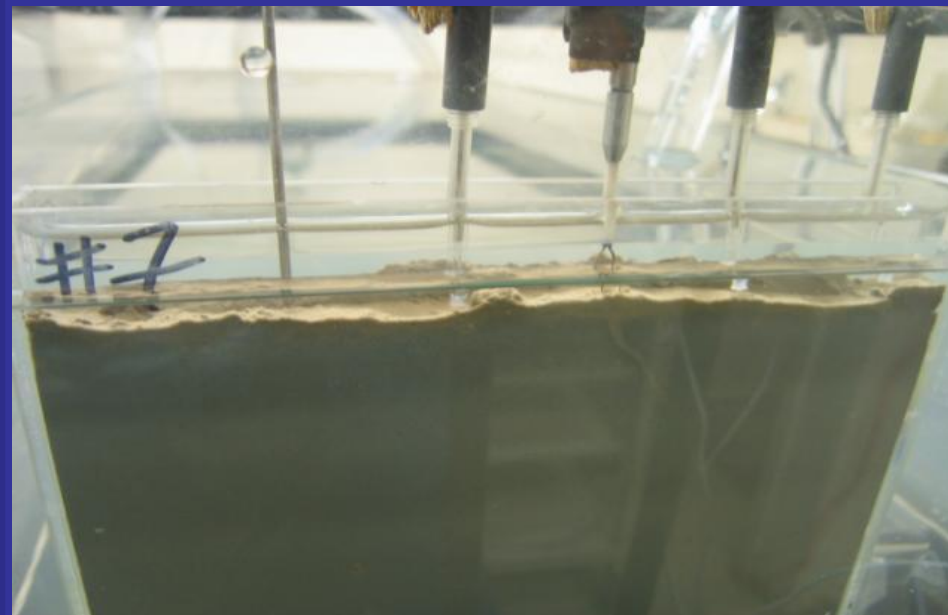
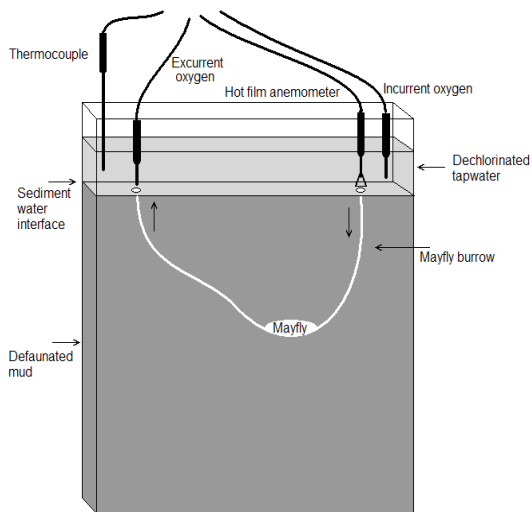
Mayflies



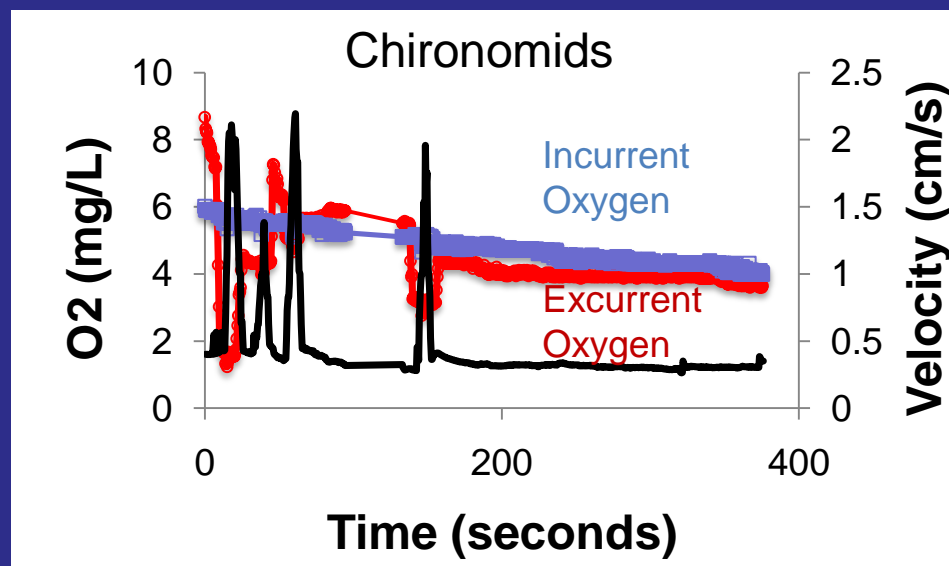
Chironomids



Bioirrigation and SOD



Edwards et al. 2009



Edwards et al.

Chironomus versus *Hexagenia*

BOD	Incubation	Large		Small	
	Temperature	Chironomid	Mayfly	Chironomid	Mayfly
	4°C	64.8	240.7	34.6	192.1
	25°C	7.4	58.0	-	21.7*

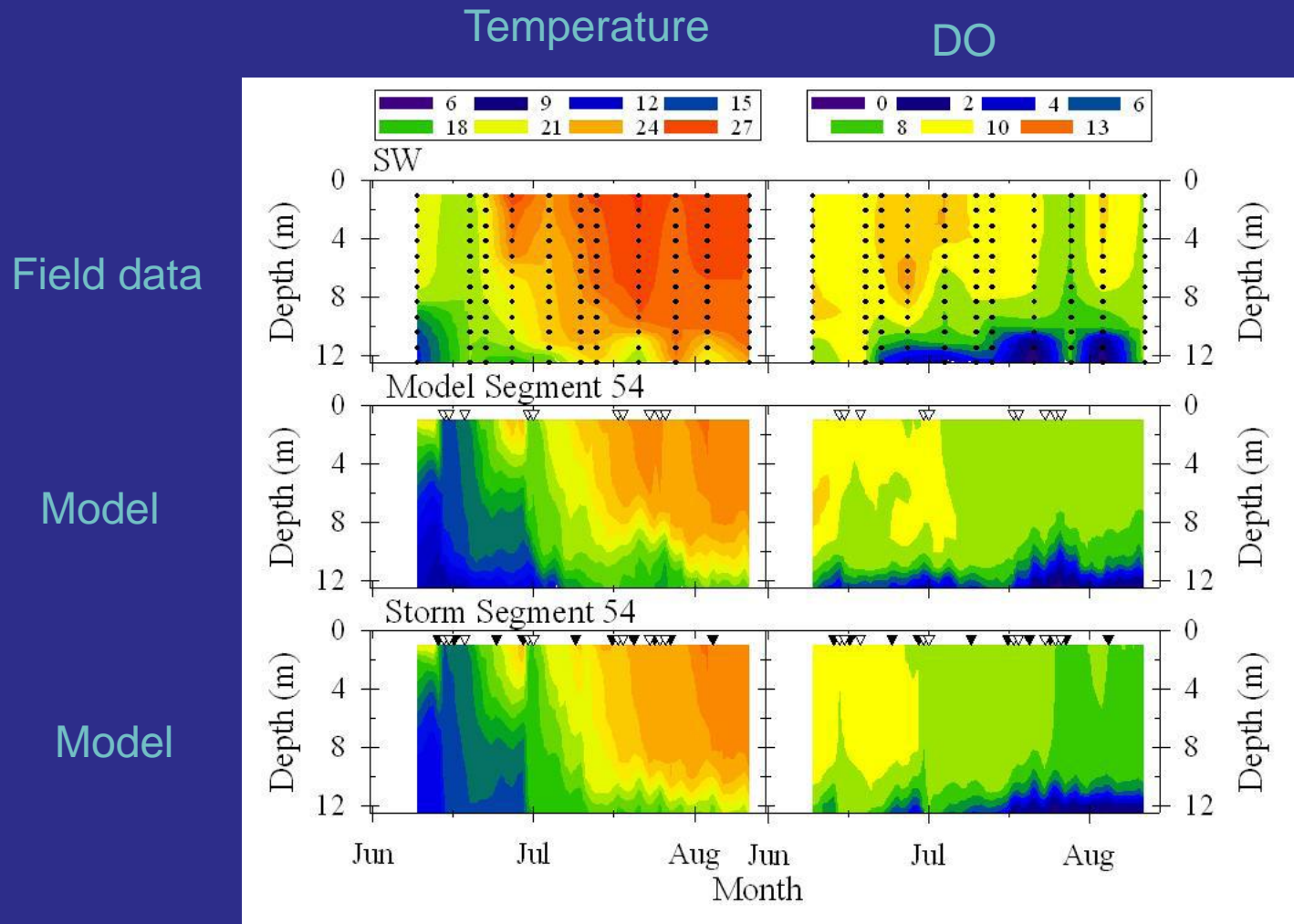
SOD	Incubation	Mayfly		Chironomid	
	Temperature	Control	mayfly	Control	chironomid
	4°C	131.5	1120	17.6	52.3
	25°C	-	233	18.4	46.7

*mg/microcosm/month

Impacts of Bioirrigation on Oxygen Demand

Study	Areal Oxygen Demand (g/m ² /month)		% HVOD (rel to EPA)
	WB	CB	
EPA depletion rates		7.0	100
Matisoff and Neeson (2005)	7.6	6.9	99
Smith and Matisoff (2008)		3.0-6.5	43-93
Edwards et al. (2009) (Mayfly Demand)	2.4-20.8		
Edwards et al. (ms) (Chironomid Demand) (low estimate)		5.2	74

Effects of winds, storms on HOD



Effects of winds, storms on HOD

With more storms:

- * wind-induced periods of entrainment became more frequent
- * the hypolimnion was warmer
- * thermal stratification occurred one month later whereas autumnal turnover occurred at least one week earlier shortening the duration of stratification by 1–2 months
- * HOD rates increased 12%

Has Oxygen Demand Changed?

TABLE 1. Estimates of the sediment oxygen demand (SOD) in Lake Erie.

SOD (g O ₂ /m ² /d)	SOD (10 ⁻¹² moles O ₂ /cm ² /s)	Method	Reference
0.28 ¹ and 0.36 ¹	10.85–13.0	—	Blanton and Winkhofer (1972)
0.360 ¹	13.0	chamber experiments	Lucas and Thomas (1972)
0.43 ¹	15.6	—	Lassenby (1979)
0.290 ¹	10.5	modeling	DiToro and Connolly (1980)
0.888 ¹	32.1	dark chamber	Herdendorf (1980)
0.3–0.4 ¹	10.9–14.5	dome chamber experiment	Snodgrass (1987)
0.229	8.29	O ₂ diffusion model	Matisoff and Neeson (2005)
0.0598	2.16	flow-through experiment biocide (0–5 cm)	this work
0.112	4.04	flow-through experiment untreated (0–5 cm)	this work
0.128	4.63	flow-through experiment untreated (0–1 cm)	this work
0.103	3.47	BRNS model (0–5 cm)	this work
0.218	7.87	BRNS model (0–10 cm)	this work
0.204	7.40	whole core incubation (average)	this work

¹ Reported by Snodgrass (1987)

Conclusions

- * Biogeochemical modeling needs calibration; can calculate fluxes, SOD, impacts of benthos
- * Biogeochemical modeling results indicate that aerobic respiration $\sim \frac{1}{2}$ SOD; bioirrigation increases SOD $\sim 2X$
- * Mayflies, chironomids are bioirrigators, increase BOD, SOD
- * BOD, SOD effects of mayflies $>$ chironomids
- * Effects of BOD, SOD of mayflies, chironomids may be significant fraction of HOD
- * With more storms
 - the hypolimnion was warmer
 - thermal stratification occurred one month later and autumnal turnover occurred earlier
 - HOD rates increased
- * No evidence for change in SOD with time (but lag expected to be long)

Future Research Needs

- * Biogeochemical model calibration data set
- * Use model to predict
 - internal nutrient loadings (esp P)
 - system response times to changes in depositional fluxes
 - effects of changing macrobenthic community
- * Comparison/re-evaluation of SOD/HOD measurement techniques
- * Better quantification of effects of benthos on HOD
- * Link sediment model with hydrodynamic model (ECOFOR, Conroy et al.)