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Supplement: Walleye Egg and Larval Density and Survival in a Great Lakes Tributary

Egg Density Results

Significant effects on peak mean egg density were detected for year ($F_{1, 24}$ = 76.76, $P < 0.01$), site ($F_{5, 24}$ = 35.72, $P < 0.01$), and the site × year interaction ($F_{5, 24}$ = 25.83, $P < 0.01$; Figure S.1). In 2009, peak mean egg density at Croton Dam site 2 (56,970 eggs/m^2) was significantly higher than densities at all other sites (Tukey's honestly significant difference [HSD] test: $P < 0.01$; Figure S.1, upper panel). Peak mean egg density at Thornapple site 2 (9,425 eggs/m^2) during 2009 was significantly higher than densities at Croton Dam site 1 (1,594 eggs/m^2), Henning Park site 1 (121 eggs/m^2), and Henning Park site 2 (85 eggs/m^2; Tukey's HSD test: $P < 0.05$; Figure S.1, upper panel). There were no significant differences in egg density among sites for 2010 (Figure S.1, lower panel). However, two sites had significantly lower peak mean egg densities in 2010 than in 2009 (Tukey's HSD test: $P < 0.01$; Figure S.1): Croton Dam site 2 (56,970 eggs/m^2 in 2009; 918 eggs/m^2 in 2010) and Thornapple site 2 (9,425 eggs/m^2 in 2009; 582 eggs/m^2 in 2010).

Supplementary Table S.1. Number of nights of Walleye larval drift sampling per week during April and May 2009–2010 in the lower Muskegon River, Michigan.

Week	2009	2010
Apr 1		1
Apr 8	1	3
Apr 15	3	4
Apr 22	4	4
Apr 29	3	2
May 5	4	3
May 12	2	1
May 19	2	2

Supplementary Table S.2. Estimated mean values (with coefficient of variation [CV, %] in parentheses) for water quality variables (DO = dissolved oxygen concentration) measured during weekly Walleye egg mat sampling events at six sites (Figure 1) in the Muskegon River during March 24–May 5, 2009 (n = 7), and March 22–April 26, 2010 (n = 6). Data were not collected at Thornapple site 2 in 2009 due to the loss of a gang of egg mats there after April 21. Turbidity was not measured at egg mat sites in 2010. Also shown are estimated mean values (with SE in parentheses) of water quality variables measured at three Walleye larval drift sites (Pine Street, Thornapple, and Maple Island Road; Figure 1) in the Muskegon River during March 31–May 15, 2009–2010; results of ANOVA tests examining the effects of drift sampling site, year, and the site × year interaction on water quality variables are reported. Significant P-values (α = 0.05) are indicated in bold italics.

Year	Site or statistic	Temperature (°C)	Velocity (m/s)	Water depth (m)	Conductivity (µS/cm^2)	pH	DO (mg/L)	Turbidity (NTU)
				Egg mat sampling				
2009	Croton Dam 1	6.7 (50)	0.57 (18)	0.80 (19)	292 (5)	8.0 (2)	11.2 (7)	3.84 (76)
	Croton Dam 2	6.5 (49)	0.87 (29)	0.71 (27)	292 (5)	7.9 (1)	11.0 (7)	3.76 (64)
	Thornapple 1	6.8 (48)	0.56 (22)	0.79 (24)	300 (7)	7.9 (1)	11.2 (7)	4.46 (61)
	Thornapple 2	5.2 (39)	0.97 (20)	0.85 (9)	306 (7)	8.0 (1)	11.7 (4)	3.50 (61)
	Henning Park 1	7.1 (47)	0.87 (24)	0.70 (19)	302 (6)	8.0 (1)	11.4 (6)	4.76 (54)
	Henning Park 2	7.1 (47)	0.46 (39)	0.93 (26)	302 (6)	8.0 (1)	11.4 (7)	5.69 (53)
2010	Croton Dam 1	7.7 (40)	0.40 (10)	0.70 (20)	343 (5)	8.1 (0)	11.0 (10)	
	Croton Dam 2	7.8 (40)	0.40 (30)	0.70 (20)	348 (5)	8.1 (0)	11.1 (10)	
	Thornapple 1	8.4 (40)	0.40 (30)	0.60 (30)	353 (4)	8.2 (0)	11.6 (10)	
	Thornapple 2	8.6 (40)	0.50 (60)	0.80 (36)	352 (5)	8.3 (0)	11.5 (10)	
	Henning Park 1	9.1 (40)	0.60 (50)	0.70 (30)	362 (4)	8.3 (0)	11.8 (10)	
	Henning Park 2	9.3 (40)	0.50 (30)	0.60 (20)	361 (4)	8.4 (0)	12.1 (10)	
				Larval drift sampling				
2009	Pine Street	10.8 (0.6)			300 (4)	8.00 (0.03)	10.5 (0.2)	3.36 (0.71)
	Thornapple	10.2 (0.7)			292 (5)	7.97 (0.03)	10.5 (0.2)	3.89 (0.73)
	Maple Island Road	11.8 (0.7)			302 (4)	8.03 (0.02)	10.5 (0.2)	8.36 (1.99)
	Average	10.9 (0.4)			298 (3)	8.00 (0.01)	10.5 (0.1)	5.25 (0.81)
2010	Pine Street	12.0 (0.3)			351 (5)	8.09 (0.02)	9.4 (0.2)	0.06 (0.04)

Year	Site or statistic	Temperature (°C)	Velocity (m/s)	Water depth (m)	Conductivity (µS/cm^2)	pH	DO (mg/L)	Turbidity (NTU)
	Thornapple	11.7 (0.3)			346 (4)	8.09 (0.03)	9.4 (0.1)	0.06 (0.03)
	Maple Island Road	13.0 (0.4)			322 (10)	8.06 (0.03)	10.2 (0.2)	1.18 (0.28)
	Average	12.3 (0.2)			339 (5)	8.08 (0.02)	9.7 (0.1)	0.47 (0.13)
	ANOVA Results for larval drift sampling							
	F, year	8.232			74.25	12.581	28.840	36.270
	P, year	***0.005***			***0.0001***	***0.0006***	***0.0001***	***0.0001***
	F, site	3.211			2.470	0.192	2.984	5.804
	P, site	***0.045***			0.091	0.826	0.056	***0.004***
	F, site × year	0.058			4.880	1.286	3.804	2.503
	P, site × year	0.944			***0.010***	0.282	***0.026***	0.088

Supplementary Table S.3. Mean (with SE in parentheses) substrate composition (%) at sites of Walleye egg mat deployment (see Figure 1) in the lower Muskegon River, 2009–2010. Substrate size categories were based on a modified Wentworth scale (cobbles: ≥64.0 mm; pebbles: >16.0 mm and <64.0 mm; gravels: >2.0 mm and <16.0 mm; fines: <2.0 mm). Three samples were randomly collected from each site during each year.

Site	Year	Cobble	Pebble	Gravel	Fines
Croton Dam 1	2009	0.0 (0.0)	40.8 (17.3)	38.8 (9.8)	20.4 (7.5)
	2010	0.0 (0.0)	16.6 (10.0)	48.6 (7.0)	34.7 (15.1)
Croton Dam 2	2009	15.1 (18.5)	62.4 (22.7)	14.7 (4.9)	7.8 (3.7)
	2010	0.0 (0.0)	48.9 (32.9)	23.9 (16.4)	27.2 (30.0)
Thornapple 1	2009	0.0 (0.0)	39.6 (20.7)	23.1 (2.3)	37.3 (21.3)
	2010	0.0 (0.0)	26.7 (16.4)	28.1 (2.9)	45.2 (16.1)
Thornapple 2	2009	10.9 (13.4)	73.3 (24.2)	10.1 (5.6)	5.7 (5.2)
	2010	10.9 (13.4)	74.4 (15.6)	11.0 (6.2)	3.7 (2.3)
Henning Park 1	2009	0.0 (0.0)	67.3 (7.6)	22.1 (4.1)	10.6 (5.5)
	2010	0.0 (0.0)	73.7 (7.9)	16.0 (5.9)	10.3 (2.1)
Henning Park 2	2009	13.3 (16.3)	77.8 (11.1)	7.0 (4.6)	1.9 (1.5)
	2010	0.0 (0.0)	88.0 (6.1)	9.9 (5.3)	2.0 (1.3)

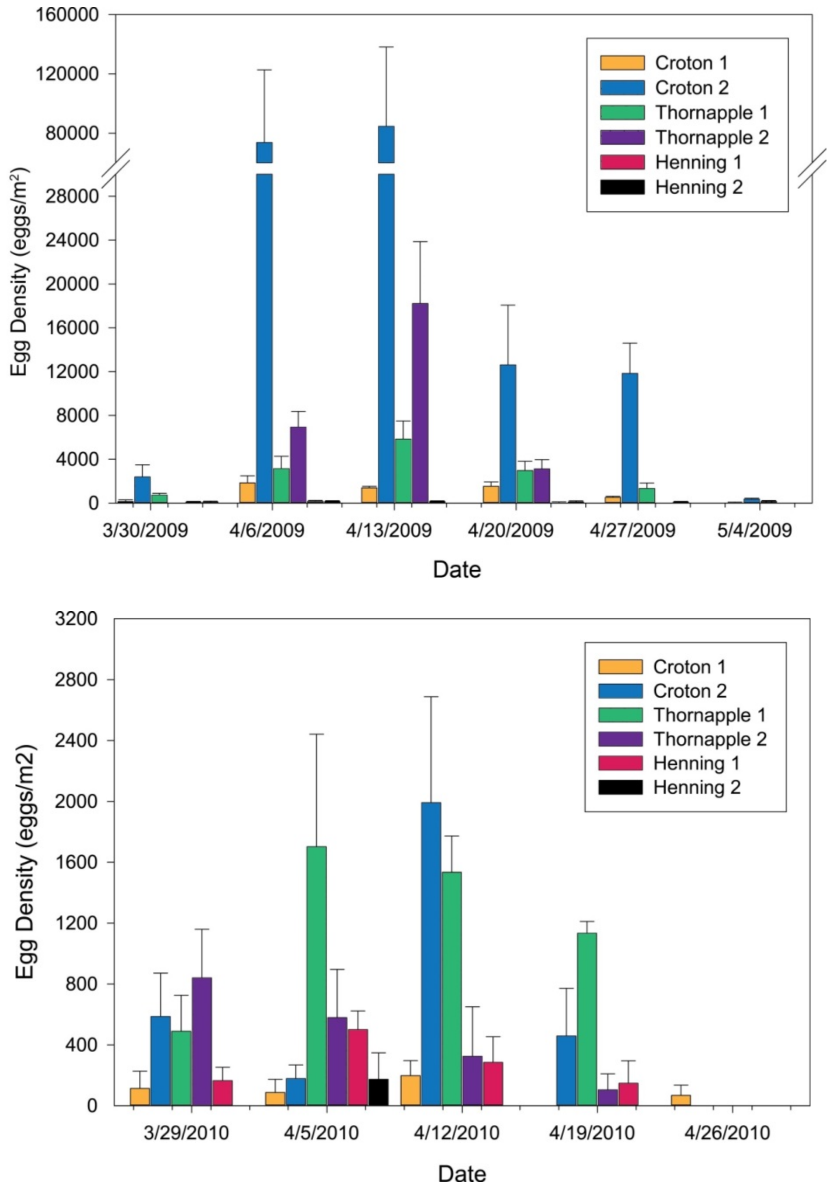
Supplementary Table S.4. Mean (with SE in parentheses) TL (mm) and weight (kg) of spawning female Walleyes on days during the first 2 weeks of the spawning season in the Muskegon River, 2009–2010. Significance tests detected differences in TL and weight between weeks of the spawning season and between years.

Year	Day	Value	*n*	*F* or χ^2 statistic	*P*
		Total length			
2009	Apr 2	675 (8.9)	47	$F_{1, 99} = 14.21$	0.0003
	Apr 8	629 (8.4)	53		
	All	651 (6.5)	100		
2010	Mar 25	677 (6.3)	66	$F_{1, 105} = 4.44$	0.038
	Mar 29	655 (8.1)	40		
	All	668 (5.1)	106		
2009 versus 2010				$\chi^2 = 4.18$	0.04
		Weight			
2009	Apr 2	3.6 (0.13)	46	$F_{1, 98} = 16.63$	0.0001
	Apr 8	2.9 (0.13)	53		
	All	3.2 (0.98)	99		
2010	Mar 25	3.6 (0.11)	66	$F_{1, 104} = 5.76$	0.018
	Mar 29	3.2 (0.15)	39		
	All	3.5 (0.94)	105		
2009 versus 2010				$F_{1, 203} = 3.53$	0.06

Supplementary Table S.5. Annual estimates of Walleye spawner abundance (adult *N*; millions), larval abundance (larval *N*; millions), and larval survival rate (*S*; %) estimated for populations in selected Great Lakes tributaries. Estimates from Mion et al. (1998) include 95% confidence intervals in parentheses. Estimates from Pritt et al. (2013), DuFour et al. (2014), and the present study include 2.5% and 97.5% credible intervals in parentheses.

Tributary	Year	Adult *N*	Larval *N*	Larval *S*
Saginaw River, Michigan	1987		3[a]	
	1988		28[a]	
Maumee River, Ohio	1993		20.4 (2.0)[b]	
	1994		13.4 (1.2)[b]	
	1995		24.8 (2.0)[b]	
	2010		29.5 (12.5–84.5)[d]	33 (16–57)[d]
	2011	0.65 (0.43–1.44)[c]	32.2 (20.8–52.1)[d]	33 (17–56)[d]
	2012	0.54 (0.38–0.86)[c]		
Sandusky River, Ohio	1993		3.2 (1.5)[b]	
	1994		3.0 (0.2)[b]	
	1995		0.8 (0.1)[b]	
Muskegon River, Michigan	2003	0.04[e]		
	2009		2.1 (1.3–3.8)[f]	12.7 (8.9–13.3)[f]
	2010		14.8 (9.4–27.7)[f]	47.3 (44.6–52.7)[f]

[a] Jude et al. 1992.
[b] Mion et al. 1998.
[c] Pritt et al. 2013.
[d] DuFour et al. 2014.
[e] Hanchin et al. 2007.
[f] Present study.



Supplementary Figure S.1. Mean (+SE) Walleye egg density on mats deployed at sites (see Figure 1) in the Muskegon River, Michigan, during 2009 (upper panel) and 2010 (lower panel). The *y*-axis scale differs between the panels.

SUPPLEMENTARY REFERENCES

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